INRIA, Evaluation of Theme
Networks and Telecommunications

Project-team HIPERCOM

March 2012

Project-team title: HIgh PERformance COMmunication (HIPERCOM)

Scientific leader: Philippe Jacquet until the end of November 2011

Pascale Minet is the new team leader until the end of December 2012.

Research center: Paris-Rocquencourt & Saclay Ile de France

Common project-team with: LIX (Laboratoire d'Informatique de l'école polytechnique)

1 Personnel

Personnel (October 2007)

	Misc.	INRIA	CNRS	University	**Total**
DR (1) / Professors		2		1	**3**
CR (2) / Assistant Professors		3		1	**4**
Permanent Engineers (3)					
Temporary Engineers (4)		1			**1**
PhD Students		3		1	**4**
Post-Doc.					
Total		**9**		**3**	**12**
External Collaborators		1			**1**
Visitors (> 1 month)		1			**1**

(1) "Senior Research Scientist (Directeur de Recherche)"
(2) "Junior Research Scientist (Chargé de Recherche)"
(3) "Civil servant (CNRS, INRIA, ...)"
(4) "Associated with a contract (Ingénieur Expert or Ingénieur Associé)"

Personnel (March 2012)

	Misc.	INRIA	CNRS	University	**Total**
DR / Professors		2			**2**
CR / Assistant Professor		4		1	**5**
Permanent Engineer					
Temporary Engineer		3			**3**
PhD Students		6			**6**
Post-Doc.		1			**1**
Total		**16**		**1**	**17**
External Collaborators				1	**1**
Visitors (> 1 month)				1	**1**

Changes in staff

DR / Professors CR / Assistant Professors	Misc.	INRIA	CNRS	University	total
Arrival		1			1
Leaving			1		1

Comments: By mutual agreement, the LRI part of the HIPERCOM project-team moved apart in 2011. This explains the departure of Professor Khaldoun Al Agha. In the same time, we have the pleasure to welcome a new research scientist at Saclay in July 2011: Aline Carneiro Viana who got her Habilitation à Diriger des Recherches. During these last four years, 7 students got their PhD thesis and moved. They were 2 at LRI, 4 at LIX, 1 at Rocquencourt, where two students will defend their PhD thesis in February and March 2012.

Current composition of the project-team (March 2012):

- INRIA Research Scientists
  - Philippe Jacquet, Team Leader until Nov 2011, Ingénieur Général en Chef des Mines (DR), habilité, at Rocquencourt
  - Pascale Minet, Team Leader from Dec. 2011, Research Associate (CR), habilité, at Rocquencourt
  - Paul Mühlethaler, Ingénieur en Chef de l'Armement (DR), habilité, at Rocquencourt
  - Cédric Adjih, Research Associate (CR), at Rocquencourt
  - Emmanuel Baccelli, Research Associate (CR), at Saclay
  - Aline Carneiro Viana, Research Associate (CR), habilité, at Saclay
- Administrative Assistant
  - Christine Anocq, shared time (with Gang and Aoste), at Rocquencourt
  - Valerie Lecomte, shared time (with Typical and Comete), at Saclay
- Faculty members
  - Thomas Clausen, Assistant Professor Polytechnique, at Saclay
  - Nadjib Achir, Assistant Professor University Paris XIII, at Rocquencourt

- Anis Laouiti, Assistant Professor Telecom SudParis, visitor at Rocquencourt

- Technical Staff
  - Yasser Toor, Engineer at Rocquencourt
  - Erwan Livolant, Engineer at Rocquencourt
  - Hana Baccouch, Engineer at Rocquencourt
  - Ala Eddin Weslati, Engineer at Rocquencourt

- PhD Students
  - Eduardo Muccelli, INRIA PhD at Saclay
  - Iskander Banaouas, INRIA PhD at Rocquencourt
  - Yacine Mezali, INRIA PhD at Rocquencourt
  - Ichrak Amdouni, INRIA PhD at Rocquencourt
  - Salman Malik, INRIA PhD at Rocquencourt
  - Ridha Soua, INRIA PhD at Rocquencourt

- Post-Doctoral Fellow
  - Juan-Antonio Cordero, INRIA PostDoc at Saclay.

Current position of former project-team members (including PhD students during the 2008-2011 period):

- Skander Banaouas, engineer at ITRON, Issy-les-Moulineaux.
- Song-Yean Cho, engineer at SAMSUNG, South Korea.
- Ulrich Herberg, researcher at Fujitsu, USA.
- Saoucene Mahfoudh, Post-doctoral fellow at Telecom SudParis.
- Marienestor Mariyasagayam, researcher at Hitachi, France.
- Matthias Philipp, engineer at AVM, Germany.
- Farid Sayah, engineer at RATP, Paris.
- Alsonso Silva, Post-doctoral fellow at Berkeley, USA.
- Yasser Toor, engineer at PHILOG, Paris.
- Georg Wittenburg, consultant at BCG, Germany.

Last INRIA enlistments

- Aline Carneiro Viana, CR1, July 2011.

Other comments:

Philippe Jacquet was the team leader until the end of November 2011. Pascale Minet is the new team leader until the end of December 2012.

2 Work progress

2.1 Keywords

Wireless Networks; Sensor Networks; Network Protocols; Network Modeling; Adaptive Algorithm; MANETs; VANETs; WSNs; Information Theory; Routing; Quality of Service; Delay Tolerant Networks;

2.2 Context and overall goal of the project

Hipercom project-team aims to design, evaluate and optimize the telecommunication algorithms. The aimed areas are protocols and standards dealing with communication support and quality of service management in wireless networks. The aimed activity fields are centered around the new networks and services supporting internet. Although we address the whole spectrum of telecommunication domain, practically the Hipercom project team is specialized in mobile ad hoc networks, mesh networks, wireless sensor networks and vehicular networks. However the thematic extends to the information theory as well as network and traffic modelling.

2.3 Objectives for the evaluation period

The objectives assigned to HIPERCOM were:

- Massive mobile dense wireless networks,
- New generation of OLSR, new services and protocols,
- Wireless sensor networks,
- Vehicular and mobile wireless networks.

2.4 Objective 1: Massive mobile dense wireless networks

2.4.1 Executive summary

Scaling properties of mobile ad hoc network lead to an increase of global capacity when the network density increases or when the packets can be stored for a while in mobile nodes instead of being immediately retransmitted.

Gupta and Kumar have shown in 2000 that the transport capacity per node in a multihop ad hoc network decreases in $1/\sqrt{N \log N}$, N being the number of nodes in the network. Therefore the global capacity of the network increases in $\sqrt{N}/\sqrt{\log N}$. This is a surprising result since in wired network a collection of nodes connected to a single communication resource has a transport capacity that just remains constant (*i.e.* the average per node capacity decreases in $1/N$).

Therefore adding space to a multihop wireless network increases the capacity: this is the space capacity paradox.

When nodes randomly move, it turns to be more advantageous to store packets for a while on mobile routers instead of forwarding them immediately like hot potatoes. When the mobile router moves closer to the destination, then it can delivers packets on a much smaller number of hops. Of course the delivery delay is much longer, but the network capacity also increases by slowing non urgent packets. This is the time capacity paradox: by slowing packets, nodes mobility increases network capacity. This was hinted the first time by Grossglauser and Tse in 2002.

Related to these scaling properties, we investigate the following issues:

- *Scaling and modeling in wireless networks.* We study the node neighborhood and the trajectory of information propagation in very dense Aloha networks. We build various models for multihop Aloha and carry out numerous comparisons in particular with CSMA. We analyze the overhead reduction offered by Fish Eye in the OLSR routing protocol.

- *Graph coloring.* We investigate coloring algorithms to allow non-interfering nodes to transmit simultaneously and evaluate the benefits in bandwidth, energy and end-to-end delays in data gathering applications. In the particular case of grid networks, we found an optimal coloring algorithm, based on vectors.

- *Opportunistic routing and DTNs (Delay/Disruption Tolerant Networks).* Using analytical models, we found the theoretical performance limits of opportunistic routing in multihop ad hoc networks using Aloha. We consider routing in DTN with protocols based on link aging rumors. We show that the minimal delay is in $\sqrt{n}$ instead of $\log n$, which is the scaling law usually admitted (derived from the scaling law of Erdos-Renyi graphs). Motivated by the connected relationship graph of nodes encounters, we show how to use delegates to assist in sensing information from a large number of mobile nodes, while avoiding the use of costly infrastructures.

- *Network coding.* Network coding is a promising scheme, based on coding packet superposition, which allows disseminating information with asymptotically optimal performance. By "asymptotically optimal" we mean that the capacity of the scheme tends to be optimal when the volume of data to be disseminated tends to infinity. We have proved that the performance of wireless random network coding are optimal in the following network model: the Erdos-Renyi random graph model and the unit disk random graph model.

2.4.2 Personnel

Cédric Adjih, Ichrak Amdouni, Emmanuel Baccelli, Skander Banaouas, Aline Carneiro Viana, Song Yean Cho, Thomas Clausen, Philippe Jacquet, Erwan Livolant, Saoucene Mahfoudh, Salman Malik, Amina Naimi Meraihi, Pascale Minet, Paul Mühlethaler, Alonso Silva, Ridha Soua, Yasser Toor.

2.4.3 Project-team positioning

The seminal papers of Gupta Kumar and Grossglauser and Tse have given rise to a strong flow of litterature since 2000 addressing space-time scaling of mobile ad hoc networks under various models.

Our peer group for network scaling is TREC in INRIA. Due to the important development of these issues, there are a lot of international groups working on these issues, such as Berkeley, EPFL, Rice, Stanford, UCLA, etc.

In wireless networks, disruption may occur because of the limits of wireless radio range, sparsity of mobile nodes, energy resources, attack, and noise. This explains the interest of DARPA on disruption-tolerant networking. In the modeling and studies of scaling laws, we have many competitors such as Berkeley, EPFL, etc. However, our team has the peculiarity not only to conduct analysis of scaling laws but also to design and implement efficient protocols. We have a peer team in Australia with the Macquarie university.

2.4.4 Scientific achievements

a) Scaling and models

a1) Scaling and spatial capacity in non uniform wireless networks We found a more precise instance of Gupta- Kumar result by using a simple but realistic network model based on slotted ALOHA with Poisson traffic. It turns out that when the traffic density increases then the average node neighborhood area shrinks so that the average encircled traffic load remains constant with an analytical expression..

In their original model Gupta and Kumar assume that the traffic density is constant, which is far from realistic. However we have derived similar generalized results when the traffic density is not uniform. In this case, the heavier is the local traffic, the smaller are the local neighborhood and the larger is the number of hops needed to cross the congested region. Therefore the shortest paths (in hop number as computed by OLSR) will have a natural tendancy to avoid congested are. The path tend to follow trajectory that have analogy in non linear optic with variable indices.

a2) Time capacity and node mobility In their seminal paper, Grossglauser and Tse have shown how a simple two hop routing protocol in a mobile network leads to a $O(1)$ per node bandwidth share in the channel bandwidth. This would lead to a $O(n)$ transport capacity for such protocol. The idea is to use the node mobility and to wait for the relay node to in range to the destination. The consequence is that the time delivery increases in $\sqrt{n}$ times the node traversal time of the network area at average node speed. For a city of 1,000,000 nodes with traversal time of 1 hour, this would lead to one month delivery delay. The condition is that the nodes motion scheme are i.i.d. and ergodic on the whole area, for example such as a Brownian motion or a random walk. We assume that the motion model is the random walk, we prove that a scheme based on Relative bearing would lead to a transport capacity of $O(\frac{n}{\log n \log\log n})$, while the packet delivery is finitely proportional to traversal time. Since the random walk is more realistic than the Brownian motion, we consider our result to have practical impact in urban networking. Furthermore the protocol works also very well on any generalized random walk models based on free space motion with persistent heading. This algorithm has application in Intelligent Transport System.

a3) Overhead reduction in large networks The first limitation of multihop wireless network is the size of the overhead per node that increases linearly with the size of the network. This is a huge improvement compared to classic internet protocols which have quadratic overhead increases. Nevertheless this till limit the network size to some thousands. We have analyzed the performance of OLSR with Fisheye feature that significantly reduce the overhead with respect to distance. In theory the overhead reduction allows to network size of several order of magnitude. Anyhow the tuning of the overhead attenuation with distance must be carefully done when the network is mobile, in order to avoid tracking failure. We showed that an overhead reduction within square root of the network size achieve this goal.

An alternative way to overhead reduction is ad hoc hierarchical routing and Distributed Hashing Table. Work has just begun in this area.

a4) Aloha models We have developped various models for Aloha in multihop ad hoc networks. With these models we have compared slotted and non-slotted Aloha and CSMA on a fair basis i.e. when all the protocols are optimized. We have also studied the effect of the parameters such as the fading, the power decay, the transmission range on the performances. We have used these models to study variants for Aloha. The first variant is an opportunistic Aloha which takes advantage of fading. The second variant is a cognitive network using Aloha. All these studies are joint work with TREC.

We address the propagation speed in opportunistic Aloha network. We assume that the network is dense enough to be connected and we compare the performance of opportunistic routing compared to classic routing such as OLSR. We show that the random variation of the reception area in Aloha can be used to improve the performance of multihop routing. Instead of sending the packet to a definite relaying node and wait for the packet to be eventually received, the packet is relayed by the first relay node that receives it, being the closest to the destination. This strategy takes advantage of the natural range variation of Aloha transmission by favoring longer hop compared to averaged hops as with OLSR.

a5) Optimization of transmission placement in slotted wireless networks We address the question: what is the optimal placement of simultaneous emitters in the plan. The target is to have the largest area of reception around each transmitter for a given density of emitter. We take Aloha, which as Poisson shot model, has a closed formula for the average reception area, and we compare with slotted CSMA and slotted colouring scheme. We show that depending on minimal SNR and propagation conditions that colouring and CSMA performs around 50% better than Aloha, while an optimal grid pattern (triangular) achieve again 50% more. The colouring scheme consists into having simultaneous emitters separated by a fixed minimal distance, while with CSMA, this minimal distance is fixed by carrier sense (but the energy makes the distance varying). The consequence of this analysis is that:
(i) CSMA and colouring perform similarly although are based on different technologies.
(ii) CSMA is shown to have good performance for such a simple scheme, but carrier sense level must be adapted with node density.
(iii) the optimal scheme, which be resource demanding in protocol exchange, cannot give more than twice Aloha which is the simplest scheme, questioning the need of additional complexity.

b) Graph coloring

b1) Coloring in wireless networks Coloring is used in wireless networks to improve communication efficiency, mainly in terms of bandwidth, energy and possibly end-to-end delays. Nodes access the medium according to their color. It is the responsibility of the coloring algorithm to ensure that interfering nodes do not have the same color.

b2) Complexity results about the h-hop coloring problem In the paper we published at the WMNC 2011 conference, we define the h-hop node coloring problem, with h any positive integer, adapted to two types of applications in wireless networks. We specify both general mode for general applications and strategic mode for data gathering applications. We prove that the associated decision problem is NP-complete.

b3) Grid coloring and the Vector-Based Coloring Method We also focused on wireless sensor networks with grid topologies. How does a coloring algorithm take advantage of the regularity of grid topology to provide an optimal periodic coloring, that is a coloring with the minimum number of colors? We propose the Vector-Based Coloring Method, denoted VCM, a new method that is able to provide an optimal periodic coloring for any radio transmission range and for any h-hop coloring, $h \geq 1$. This method consists in determining at which grid nodes a color can be reproduced without creating interferences between these nodes while minimizing the number of colors used. We compare the number of colors provided by VCM with the number of colors obtained by a distributed coloring algorithm with line and column priority assignments. We also provide bounds on the number of colors of optimal general colorings of the infinite grid, and show that periodic colorings (and thus VCM) are asymptotically optimal. Finally, we discuss the applicability of this method to a real wireless network.

b4) Coloring in dense wireless networks we also designed OSERENA "Optimized SchEduling RoutEr Node Activity", a distributed coloring algorithm optimized for dense wireless networks, where the limited capacity in bandwidth and memory do not allow the nodes to store or send their 2-hop neighbors.

c) Opportunistic routing and DTN

c1) Opportunistic routing The model of wireless networks based on dynamic graph does not well assess the real processes in a wireless network. In particular the range of transmission can greatly vary between packets, the graph keeping only the average range. Opportunistic routing consists into taking advantage of temporary extension of the transmission range in orger to gain several hops.

We have strong established theoretical performance limits in opportunistic routing. The limits are based on realistic interference scenarios in slotted Aloha. We have also investigated the impact of mobility on this theoretical limits.

We have designed an opportunistic routing protocol whose performance are within a small margin of the theoretical limits.

We have also conducted studies to support intelligent and adaptive forwarding, which allows a good trade-off between reliability and resource-efficiency. We then design a new protocol, called GrAnt, a new prediction-based forwarding protocol for complex and dynamic delay tolerant networks (DTNs). The proposed protocol uses the Ant Colony Optimization (ACO) metaheuristic with a greedy transition rule. This allows GrAnt to select the most promising forwarder nodes or allow for the exploitation of previously found good paths. The main motivation for using ACO is to take advantage of its population-based search and the rapid adaptation of its learning framework. Considering data from heuristic functions and pheromone concentration, the GrAnt protocol includes three modules: routing, scheduling, and buffer management.

c2) Intermittent and delay tolerant networks We consider the problem of routing in these networks, with the sole assumption that the speed of the node mobility is less than the speed of transmitting a packet to a neighbour. We compare this problem with sound propagation in liquid. We show that various pattern of mobility and network clustering can be described by a single parameter such as the information speed propagation.

We introduce new algorithms that route a packet toward a remote destination. The different algorithms vary depending on the buffering and the capacity capabilities of the network (i.e. if one or more copies of a packet can be sent and/or be kept). All algorithms are based on link aging rumors across connected components. The packet bounces from connected components to connected components, thanks to node mobility. We establish several analytical properties using an analogy with the sound propagation in liquid where molecules creates temporary connected components where sounds travel very fast.

Previous models assumed that the propagation of information path evolves like in a dynamic Erdos-Renyi graph leading to an epidemic flooding in O(log n) or O(1), n being the number of nodes in the network. We disprove the Erdos-Renyi model by showing via space-time considerations that the set of information path from a source to a destination is in fact much smaller than the path set in the Erdos-Renyi model. This lead to a much larger minimal delay in square root of n instead of log n. This correspond to a bounded maximal information propagation speed, whose estimate depends on the mobility model and the node density, and is root of multivariate explicit Bessel formulas.

Additionally, we have also considered the problem of data collection in global sensing and intermittently connected systems while avoiding the use of costly infrastructures (e.g., 3G). Motivated by the observation that node encounters are sufficient to build a connected relationship graph, we propose to take advantage of such inherent interactions to transform some mobile devices into delegates. We use then opportunistic delegation as a data traffic offload solution by investigating two main questions: (i) How to gain insights into social mobile networking scenarios?, (ii) How to utilize such insights to design solutions to alleviate overloaded 3G networks?. Our solution leverages usage of mobile applications requiring large data transfers by channeling the traffic to a few, socially important users in the network called VIP delegates. Mobile collectors need then only to meet delegates that, in turn, are responsible for gathering data from a subset of standard producers. We first investigate several delegation strategies based on the relative importance of nodes in their social interactions. Second, by considering a prediction strategy that estimates the likelihood of two nodes meeting each other, we investigate how the delegation strategies perform on predicted traces.

d) Network Coding

Network coding is a promising scheme, based on coding packet superposition, which allows disseminating information with asymptotically optimal performance. By "asymptotically optimal" we mean that the capacity of the scheme tends to be optimal when the volume of data to be disseminated tends to infinity.

We study network coding for multi-hop wireless networks. We focus on the case of broadcasting where one source transmits information to all nodes in the network. Our goal is energy-efficient broadcast, that is, minimizing the total number of transmissions for broadcasting to the entire network. Note that this is a different problem for the classical problem of capacity maximization; and assuming we are far from the network capacity limit, hence in fact, we could assume interference-free transmissions.

Our previous results, they had shown that network coding (and a simple coding strategy) was able to reach optimality for assymptotically large and dense networks, with assympotically 100 % of the received transmissions being useful (innovative). We extended the results with the combined use of connected dominating sets and network coding: we were able to quantify (and bound) the benefits of network coding in networks where the area of the network stays fixed, and only the density increases.

We have proved that the performance of wireless random network coding are optimal in the following network model: the Erdos-Renyi random graph model and the unit disk random graph model. In particular we show in the Erdos-Renyi the network coding capacity rate outperforms any Connected Dominating Set strategy by a factor of order log n. In the unit disk model the gain is larger than 60%. The result is based on the analysis of the connectivity stretch ratio of the random graphs. The connectivity stretch ratio is the ratio of the smallest degree over the connectivity number, and the connectivity stretch ratio tends to one in the two graph models.

2.4.5 Collaborations

- Professor Bernard Mans, Macquarrie University, Sydney, Australia,
- TREC INRIA team,
- Professors Anelise Munaretto and Myriam Regattieri Delgado from Federal Technological University of Parana (UTFPR), Brazil,
- CNRS researcher Marcelo Dias de Amorim, LIP6/UPMC, France,
- Mathias Boc, CEA LIST, France,
- Computer Science Department, Sapienza University of Rome, Italy,
- University of St. Andrews, UK.
- Professor Leila Saidane, ENSI, Tunisia.

2.4.6 External support

- the associated team with Macquarie university;
- the ETARE project;
- the OPNEX project.

2.5 Objective 2: New generation of OLSR, new services and protocols: Executive summary

The user of a mobile network very quickly experiences problems with quality of service: links fade, connectivity disrupts, delays accumulate.

The connectivity continuity is the most important problem. Trivial in the wired world where a link failure is a rare event, it becomes problematic in the mobile world where link failure caused by mobility are frequent and normal. The first experiments of mobile ad hoc networks with regular internet protocols miserably failed simply because either the protocol was to slow to recover link failure, or when tuned appropriately was generating such a huge overhead that the network collapsed under its own weight. A new generation of routing protocols has arised that allow a suitable control of connectivity in mobile networks. Among them the *Optimized Link State Routing* combines the optimization of overhead for mobile networks and the full internet legacy. It naturally provides path redundancy which accelerates link failure recovery.

Quality of service has become the central requirement that users expect from a network. High throughput, service continuity are critical issues for multimedia application over the wireless internet where the bandwidth is more scarce than in the wired world. QoS support including an admission control based on the available bandwidth, a crucial step of quality of service, is an important and difficult problem.

Since the bandwidth is scarce, any multimedia application such as video streaming is resource demanding. For example a TV broadcast that uses a mesh network will rapidly exhaust the bandwidth if point-to-point communications are used. There are two classes of multicast protocols: the tree or mesh based protocols and the network coding protocols. In the first class the protocols take advantage of the relatively small size of the recipient node set. One can show equivalent results of Gupta and Kumar scaling properties but in the multicast plan when the ratio of recipient versus network size is a fundamental parameter. When this ratio tends to one the performance naturally worsen. We extend our scaling properties of multicast, generalizing Gupta and Kumar result of 2000. The multicast capacity gain over unicast is in $\sqrt{n}$. We show that the multicast protocol MOST based on Steiner trees achieves this gain order. When the recipient set is the whole network, one can apply the network coding scheme with random packet combination. In network coding the packets are no longer isolated: relay nodes makes linear combination of packets and transmitted mixed packets. In theory the performance of network coding is better than isolated packet multicast. In practice network coding is simpler to operate does not need topology management such as spanning trees or Connected Dominating Set. The reason for this is highly non intuitive, as if packet superposition was acting like state superposition in quantum mechanic, leading to non expected results.

A significant issue in the ad-hoc domain is that of the integrity of the network itself. Routing protocols allow, according to their specifications, any node to participate in the network - the assumption being that all nodes are behaving well and welcome. If that assumption fails - then the network may be subject to malicious nodes, and the integrity of the network fails. An important security service over mobile networks is to ensure that the integrity of the network is preserved even when attacks are launched against the integrity of the network.

As a consequence, the services and protocols that need careful adaptation are:

- OLSRv2 to make the OLSR routing protocol more modular, more extensible and more efficient than its predecessor;
- Gateway OLSR/OSPF to interconnect the OSPF world and the OLSR world, taking advantage that both protocols are link state based;
- Quality of service (QoS) support to take into account the QoS requirements of applications, being aware of interferences;
- Multicast to allow an efficient transmission of multicast flows;
- Autoconfiguration to allow nodes to get a globally unique address;
- Security to counter attacks against the routing.

The most important lesson that must be retained is that most of these optimization become NP complete, which is a significant complication compared to their counterpart in the classical wired world. The reason for the NP-completeness is two-sided: on one side the co-interferences make impossible an optimization link by link, on the other side, the large dispersion of performance measurement makes simple heuristic ineffective. As an example, routing with respect to shortest delay average does not guarantee smallest probability of high delay.

2.5.1 Personnel

Cédric Adjih, Ichrak Amdouni, Emmanuel Baccelli, Skander Banaouas, Aline Carneiro Viana, Thomas Clausen, Philippe Jacquet, Erwan Livolant, Saoucene Mahfoudh, Salman Malik, Amina Naimi Meraihi, Yacine Mezali, Pascale Minet, Paul Mühlethaler, Ridha Soua, Yasser Toor.

2.5.2 Project-team positioning

The exponential acceleration of the activity about multihop wireless networking makes difficult an exhaustive description of the state of the art. Almost all research institutions in STIC have a team working on services and protocols for mobile ad hoc wireless networking, not talking of industrial research centers. In France to the exception of France Telecom and military manufacturers there are not many industrial teams on this subject.

Mobile ad hoc networking is splitted into two main schools: the reactive school (UCSB, Rice, Nokia, Terminode, etc), and the proactive school (UCLA, Boeing, BAE, INRIA, Frei Funk, Keio University, Hitachi, etc). There is now a large community (OLSRD) which extends a large library on OLSR.

INRIA is active in this community and still has a leading edge despite the disproportion of manpower.

2.5.3 Scientific achievements

Optimized Link State Routing (OLSR) The routing protocol OLSR is universally known in the mobile wireless community (more than 500,000 hits on Google). It has numerous implementations and is used in many wireless networks. It is a proactive protocol with full internet legacy which is based on partial topology information exchange, that non the less provide optimal path with additive metrics (such as BGP/OSPF). It is an experimental RFC within IETF and soon will become a full standard under the name

OLSRv2. For more details on OLSRv2 see subsection 3.5.

Gateway OSPF/OLSR The MANET extension protocols being largely experimental, we have developped a software that enables a gateway between OSPF and OLSR and allows the convergence of both protocols on existing software. This software has been implemented on the MANET/OLSR demonstrator of CELAR (MoD).

OSPF extension for wireless mesh networking Long a near-future myth, ad hoc networks are now becoming a reality as a variety of wireless mesh networks are being deployed. Wireless mesh networks are a specific kind of ad hoc network, where terminals are essentially fixed. Even in such cases, which somewhat resembles usual networks, specific routing protocols have nevertheless to be employed, to cope with the characteristics of wireless, multi-hop communications. Such characteristics include scarce bandwidth over inherently unreliable, versatile, semi-broadcast links, and absence of a central authority in general. One of the main difficulties in this context is to cope with contradictory requirements such as, on one hand, dealing with bandwidth scarcity, which typically requires decreasing control traffic, while on the other hand, dealing with unreliable, versatile links which typically requires increasing control traffic. The two prominent routing protocols that have been developed for ad hoc networks and studied over the past decade, are the IETF standards AODV and OLSR. AODV is based on a reactive scheme (i.e. on-demand flooding to discover a path to a new destination), while OLSR is based on a proactive scheme, which is essentially an optimization of link state routing (i.e. pre- provisioning of paths to all possible destinations). OLSR is to date the most deployed such protocol, as it powers numerous wireless mesh community networks that currently flourish in various cities throughout Europe and North America. Based on this experience, the integration of ad hoc networking in the "standard" networking body is going further in several directions. One direction is the IEEE 802.11s standardization effort, which uses AODV and OLSR-derived algorithms to provide wireless mesh routing capabilities below IP. Another direction, spearheaded by the IETF, is the extension of IP routing standards such as OSPF to support ad hoc routing: in this realm we recently spun RFC 5449, as well as a series of academic publications on the subject. The idea behind extending OSPF to support ad hoc networks comes from a simple observation: OSPF is algorithmically quite similar to OLSR, as both are based on a proactive, link state approach. As on the other hand OSPF is a well-understood, widely deployed, industry-standard protocol, employing it to integrate ad hoc networks with existing infrastructure is considered by users as an easy migration path.

Multi-metric routing Quality of service involves finding routes between two nodes in the network that satisfies a number of constraints. These constraints could be the requested bandwidth, the maximum delay, the minimum loss probability, the reliability of links, etc. This problem is NP-Complete because it combines additive metrics in the optimization problem. Hipercom proposed heuristics for finding routes that respect up to four metrics when calculating routes between source and destination. Another QoS issue is the creation of models that estimate the actual value of a metric. For example, computing the available bandwidth or the transfer delay on a link, etc. is very complex in a non-deterministic medium access such as WiFi. To resolve this problem, we developed a model for estimating the available bandwidth in a wireless network. This model is based on considering interfering links in cliques, after which we provide the maximum capacity that could be deployed in a clique. We may still enhance the model by adding a scaling factor to the clique equations in order to become more accurate when compared to real measurements.

In particular we have investigated the metric based on packet delay distribution. Since propagation delays between routers are negligible, most delays occur in queueing and medium access control processing. Contrary to previous common belief there is no need of network synchronization. The objective is to proactively determine the delay in absence of packet data traffic. The estimate of delay distribution is done via analytical method. In order to keep control on quality of service flows we use source routing forwarding options.

Multicasting in mobile ad hoc networks The goal of multicast protocols is to allow the network to deliver the multicast information to interested users. The multicast protocol builds and maintains a structure that will provide routes to all nodes in the multicast group; hence, they will receive the information multicast in their group. Multicast protocols can be classified according to the following criteria:

- *Multicast structures maintained by the multicast protocol: trees or meshes.* We distinguish:
  - Shared tree. In the shared tree based family only one tree is built for each multicast group. Sources are not required to be a part of the multicast structure; they need an entry point to send their data to (the root of the tree for example, or the nearest tree member).
  - Source tree based. In the source based family, a tree is built for each tuple $< source, multicastgroup >$. Notice that IGMPv3 enables multicast source selection, which is straightforward with this kind of multicast tree.
  - Mesh based protocols maintain a structure containing all the participants to the multicast group; all the multicast sources and the multicast receivers. The target is to have several paths from one sender to each destination. Data is relayed and delivered through different paths to the receivers. Hence, it increases the robustness against link breakages. This robustness against the topology changes in mesh based protocols, are however more demanding in terms of bandwidth consumption compared to the tree based protocols which are more efficient in terms of resource usage.
- *Flat/Overlay structure.* In the flat category, all nodes are assumed to handle multicast data and can participate in the multicast structure building and maintenance (tree, mesh). In the overlay category, multicast nodes of a same group build and maintain a virtual structure on top of physical structure that links all the participants using unicast tunnels. In this case, not all nodes within the network are supposed to know about the multicast protocol routing, they only have to forward the encapsulated multicast data that flows inside the unicast tunnels.

Performance evaluation of multicast protocols The HIPERCOM team-project has designed three multicast protocols:

- SMOLSR, an optimized broadcast protocol using the multipoint relays defined in OLSR;
- MOLSR, a multicast protocol maintaining a source tree structure and using the topology information provided by OLSR;

- MOST, a multicast protocol maintaining a shared tree structure and using overlays. It also uses the topology information provided by OLSR.

We have performed extensive simulations on the INRIA cluster with NS2 to quantitatively study the behavior of each protocol in different scenarios and configurations. The quality of the multicast is evaluated by the packet delivery ratio while we have varied the number of multicast groups, the number of sources, the number of clients in a group, the source rate, the Broadcast rate, the number of network nodes and the mobility. The overhead induced by the multicast traffic is given by the measure of the number of retransmissions per multicast packet, also called average packet forwarding. The measures obtained through NS2 are then compared to those obtained by a graph simulator which shows similar results. With these results, we can deduce the applicability domain of each multicast protocol studied: SMOLSR, MOLSR and MOST.

We have derived a theoretical upper bound of the multicast capacity in wireless network. This result is an extension of Gupta and Kumar result about unicast capacity in wireless network. It is shown that the multicast delivery allows an increase of capacity of the order of the square root of the size of the multicast group compared to the attainable capacity if only parallel unicast connections were used. We have also shown that the protocol MOST actually attains this upper bound.

Autoconfiguration Thomas Clausen is co-chair of the IETF working group *Autoconfiguration in MANET*.

A preconditioning for all routing protocols, OLSR included, is that each node is identifiable through an unique identifier We have developed, and published, a simple autoconfiguration mechanism for OLSR networks, aiming a solving the simple but common problem of one or more nodes emerging in an existing network. Our solution is simple, allowing nodes to acquire an address in two steps: first, acquiring a locally unique address from a neighbor node. Then, with that locally unique address and using the neighbor from which the address was acquired as proxy, obtaining a globally unique address.

Furthermore, autoconfiguration also addresses the problem of keeping the consistency of a nomadic network while changing frequently its attachment to the internet. A mobile network (MONET) is a specific network which has the ability to move as a unit while maintaining its connectivity to Internet. Examples of such networks are those deployed in public transportation systems (buses, trains, taxis, etc.) allowing travelers to exchange information and access to the global Internet. Our main research topic in this area concerns radio resource management during mobility. We proposed a resource reservation strategy which can be used by the MONET's mobile router to prepare the grouped handover of all the supported traffic flows. This strategy is based on the predictive movement of MONET networks and showed good results in terms of lost packets and handover dropping probability.

Security in OLSR In ad hoc networks, security is a very important issue since routing nodes are anonymous. In this case, any node, could change its correct information, insert false information, take the identity of other nodes, etc. All the attacks are very easy because anybody could enter and exit the network and also the medium is wireless and open. Moreover, for the survival of a network, we need the willingness of the nodes in order to route packets to the final destination. If nodes do not cooperate correctly, the routing becomes inefficient. Our solution was to develop two different approaches, one based on intrusion detection that checks the incoherence in the routing protocols and then sends alerts to nodes in order to deactivate the intruders and the second is based on flow conservation that permits to check nodes that avoid forwarding. We introduced the latter property into QoS mechanisms, in order to introduce security as a metric in the routing protocol and to find reliable and secure links.

This issue is a hot issue in ad hoc networks since these networks are inherently open networks. We have reached the following results:

1. we have designed two security mechanisms to counter most of the attacks when we assume that there is no compromized nodes in the network; the first one has been implemented on the MANET/OLSR demonstrator of CELAR (MoD).

2. in presence of compromized nodes we have proposed mechanisms to detect compromised nodes or links and to remove such nodes or links in a numerous configurations of attacks.

A significant issue in the ad-hoc domain is that of the integrity of the network itself. Routing protocols allow, according to their specifications, any node to participate in the network - the assumption being that all nodes are behaving well and welcome. If that assumption fails - then the network may be subject to malicious nodes, and the integrity of the network fails.

An important security service over mobile networks is to ensure that the integrity of the network is preserved even when attacks are launched against the integrity of the network.

Hipercom@LIX has allied with TANC@LIX - a research group specialised in cryptography and security, which has developed strong security mechanisms yielding short cryptographic signatures which can be rapidly verified. The goal of this Hipercom/TANC alliance is to develop secure OLSR networks, suitable for real-world deployments where network integrity is paramount.

This effort is supported by DIGITEO Labs.

2.5.4 Collaborations

- Many contractual collaborations:
  - MoD (QoS, security, interconnection between the OLSR and OSPF routing domains),
  - Hitachi (Vehicular applications, OLSRv2),
- Non contractual:
  - BAE (OLSRv2),
  - Deutsche Telekom Labs/TU-Berlin, Germany,

2.5.5 External support

- MoD (QoS, security, interconnection between the OLSR and OSPF routing domains),
- Hitachi (Vehicular applications, OLSRv2).

2.6 Objective 3: Wireless Sensor Networks: Executive summary

2.6.1 Executive summary

The diversity of the applications supported by wireless sensor networks explain the success of this type of network. These applications concern as various domains as environmental monitoring, wildlife protection, emergency rescue, home monitoring, target tracking, exploration mission in hostile environments... Sensor nodes are characterized by a small size, a low cost, an advanced communication technology, but also a limited amount of energy. This energy can be very expensive, difficult or even impossible to renew. That is why, energy efficient strategies are required in such networks in order to maximize network lifetime.

Solutions to maximize network lifetime can be classified into four categories:

- *Topology control:* These strategies adjust the transmission power of wireless nodes to spare energy;
- *Reduction of the volume of information transferred:* These strategies aggregate data with or without clustering, optimize network flooding, tune the periodicity of information refreshment, etc.;
- *Nodes activity scheduling:* as the sleeping state is the radio state consuming the least energy, these strategies make nodes sleep in order to spare energy, while ensuring network and application functions.
- *Energy efficient routing:* Such strategies notice that a multihop transmission is energy consuming and reducing the energy spent in the transmission of a packet from its source to its destination would increase network lifetime. Moreover, avoiding nodes with a low residual energy would also contribute to prolong network lifetime. Avoiding nodes that already have a high traffic load would reduce medium access contention, collisions if the medium access type is CSMA-CA and then spare energy lost in useless transmissions.

In wireless sensor networks (WSNs), we focus more particularly on:

- *Energy efficiency*, that is the general concern in WSNs. we have shown how to extend OLSR and make it energy-efficient.
- *Cross-layer based routing.* We have designed a cross layer protocol for surveillance Wireless Sensor Networks (WSNs) which monitor infrequent events. Thus, the power is mainly consumed in the sensing task. We show that WSNs can operate with a low duty-cycle of their transceivers if they use the Receiver Initiated MAC protocol and an opportunistic geographic routing to deliver the packet to the sink. The main idea is that a node transmits its packet to the next awake node as long as this decreases the remaining distance to the sink.
- *Node activity scheduling and spatial reuse of the bandwidth.* We design and implement a node coloring algorithm to allow nodes to sleep to save energy without impacting network connectivity. Non -interfering nodes transmit simultaneously, enabling a spatial bandwidth reuse.

- *Security.* We introduce two new cryptographic protocols of different complexity and strength in limiting network degradation caused by sinkhole attacks on tree-based routing topologies in Wireless Sensor Networks (WSNs).

- *IPv6 support.* Wireless sensor networking is a key element of the Internet of Things (IoT), a substantial part of the billions of smart objects that are soon to blend into the global IP network. The Internet Engineering Task Force (IETF) is currently engaged into multiple efforts addressing the limitations of existing standards concerning wireless sensor IP networking. Some standards in development aim at providing multi-hop wireless sensor communication with IPv6, which requires specific routing protocols, efforts in which we actively participate.

2.6.2 Personnel

Cédric Adjih, Ichrak Amdouni, Emmanuel Baccelli, Skander Banaouas, Aline Carneiro Viana, Thomas Clausen, Philippe Jacquet, Erwan Livolant, Saoucene Mahfoudh, Salman Malik, Yacine Mezali, Pascale Minet, Paul Mühlethaler, Ridha Soua.

2.6.3 Project-team positioning

Many teams are working on the WSN topic, among them Berkeley, RICE, Stanford, UCLA, to name a few. This is due to the high number and variety of applications supported by WSNs. The HIPERCOM project-team both performs theoretical studies and carries out design and implementation of WSN protocols. HIPERCOM works in close collaboration with industrial end users (EDF, DCNS, EADS, CNES...) and other academic partners. Peer teams are the universities of Clermont-Ferrand (LIMOS), Toulouse (LATTIS), the FUN INRIA project-team and the ENSI team of Leila Saidane, etc.

2.6.4 Scientific achievements

Energy efficient routing Energy efficiency is a key issue in wireless ad hoc and sensor networks. Energy efficient routing is a way to improve energy efficiency and prolong network lifetime. We have shown how to extend the standardized OLSR routing protocol, in order to make it energy efficient. We have first defined an energy model for multihop transmissions. The energy cost of a one-hop transmission is evaluated, taking into account the energy lost in transmitting, receiving, overhearing and interferences. We have then evaluated the energy cost of multihop transmissions. Because of radio interferences, the selection of a unicast path, between a source and a destination, ensuring that each node has sufficient residual energy is NP-hard (see Mans 2006).

The OLSR extension we propose, called EOLSR, selects the path minimizing the energy consumed in the end-to-end transmission of a flow packet and avoids nodes with low residual energy. We show by simulation that EOLSR outperforms the solution that selects routes minimizing the end-to-end energy consumption, as well as the solution that builds routes based on node residual energy. EOLSR prolonges the network lifetime of 50% compared with OLSR for a network of 200 nodes. This extensive performance evaluation allows us to conclude that EOLSR maximizes both network lifetime and the amount of data delivered.

We then show how we can improve the benefit of energy efficient routing using cross layering. Information provided by the MAC layer improves the reactivity of the routing protocol and the robustness of routes. Moreover, taking into account the specifities of some applications like data gathering allows the routing protocol to reduce its overhead by maintaining routes only to the sink nodes. We propose the strategic mode of EOLSR for that purpose.

The strategic mode of the EOLSR protocol has been implemented in the OCARI project aiming at developing a wireless sensor communication module, based on the IEEE 802.15.4 PHY layer, supporting the EDDL and HART application layer and targeting applications in power generation industry and in warship construction and maintenance.

Node activity scheduling In wireless ad hoc and sensor networks, an analysis of the node energy consumption distribution shows that the largest part is due to the time spent in the idle state. This result is at the origin of SERENA, an algorithm to SchEdule RoutEr Nodes Activity. SERENA allows router nodes to sleep, while ensuring end-to-end communication in the wireless network. The idea is to assign a color to each node, while using a small number of colors and ensuring that two nodes with the same color can transmit without interfering. This color is mapped into a time slot in which the node can transmit its messages. Any node stays awake only during its slots and the slots assigned to its one-hop neighbors, it sleeps the remaining time. We propose a generic solution able to adapt to different application requirements: general or tree-based communications, broadcast, immediate acknowledgement of unicast transmissions... The impact of each additional requirement is evaluated by simulation. For instance, for general communications with immediate acknowledgement, two-hop coloring is no longer sufficient, three-hop coloring is required.

An originality of this work lies in taking into account real wireless propagation conditions. Unidirectionnal links, late node arrivals, appearance of new links and node mobility can create color conflicts. A cross-layering approach with the MAC layer is used to solve these conflicts. We also show how cross-layering with the application layer can improve the coloring performance for data gathering applications. In such applications, the freshness and time consistency of data collected from the sensors must be ensured. SERENA enables collected data to reach the sink in a single cycle, minimizing the end-to-end delays. This property is obtained by obliging a node to select a color higher than its parent. Hence, it will transmit before its parent that aggregates the data received from its children.

A performance evaluation allows us to compare SERENA coloring algorithm with existing ones such as Distributed Largest First (DLF), TDMA-ASAP, FlexiTP or D-RAND used in Z-MAC, both in terms of number of colors and complexity. SERENA and DLF use a similar number of colors, whereas the complexity of SERENA expressed in numbers of rounds is significantly lower. TDMA-ASAP, FlexiTP or D-RAND do not support immediate acknowledgement of unicast transmissions. The immediate acknowledgement is very useful in a wireless environment prone to message losses.
Simulation results show that SERENA maximizes both network lifetime as well as the amount of data delivered to the application. The first benefit of SERENA is that less energy is lost in the idle state. Indeed, if a node has nothing to transmit and its one-hop neighbors are not transmitting, the node is sleeping. The second benefit is that SERENA contributes to significantly reduce the interference phenomenon that becomes negligible. Hence, SERENA considerably improves the energy efficiency of wireless ad hoc and sensor networks. Moreover, SERENA increases the utilization of network resources such as

bandwidth by means of spatial reuse.

A strong cooperation with the MAC layer enables an efficient time slot allocation and an early detection of color conflicts. This cooperation improves the performances of SERENA in a network where bandwidth and energy are limited.

In order to reduce the overhead induced by the coloring algorithm SERENA, we have optimized the messages used to color the network nodes, both in the general case (three-hop coloring) and in the tree case used by data gathering applications. These messages do no longer contain the priority and color of all the one-hop and two-hop neighbors, but still ensure that the nodes color themselves according to the order given by their priority. Hence, it is possible to use SERENA, even in case of large and dense networks.

SERENA with the optimized messages is implemented in C and embedded in wireless sensors provided by TELIT and implementing the MACARI protocol developped by LIMOS for the OCARI project.

Optimized routing in low capacity sensor networks Self-organization is considered as a key element in tomorrow's Internet architecture. A major challenge concerning the integration of self-organized networks in the Internet is the accomplishment of light weight network protocols in large ad hoc environments.

In this domain, Hipercom's activity with wireless sensor nodes in collaboration with the Freie Universitaet in Berlin explores various solutions, including extensions of OLSR (for example DHT-OLSR) using programmable sensor nodes co-designed by the Freie Universitaet, and provides one of the largest testbeds of this kind, to date.

Cryptographic Protocols to Fight Sinkhole Attacks on Tree-based Routing in Wireless Sensor Networks Wireless Sensor Networks (WSN) are penetrating more and more in our daily life. As a consequence, security has become an important matter for these networks. We introduce two new cryptographic protocols of different complexity and strength in limiting network degradation caused by sinkhole attacks on tree-based routing topologies in Wireless Sensor Networks (WSNs). The main goal of both protocols is to provide continuous operation by improving resilience against, rather than detection of, these attacks. The main benefit of providing resilience is that it allows operating (or graceful degradation) in the presence of attacks. Furthermore, while resilience mechanisms do not dismiss detection mechanisms, detection mechanisms often introduce more complexity and so, more weaknesses to the system, which might not justify their benefits. More specifically our two *RESIlient and Simple Topology-based reconfiguration protocols* are: RESIST-1 and RESIST-0. RESIST-1 prevents a malicious node from modifying its advertised distance to the sink by more than one hop, while RESIST-0 does not allow such lying at the cost of additional complexity.

IPv6 Protocol suite for Sensor Networks Wireless sensor networking is a key element of the Internet of Things (IoT), a substantial part of the billions of smart objects that are soon to blend into the global IP network, from actuators to home appliances, from smart meters, to smart dust. Sensor nodes are devices used for distributed and automated monitoring of various parameters such as temperature, movement, noise or radioactivity levels etc. Sensors are scattered with minimum planning with respect to their precise physical position (including the central role of the sink, if any), and the set of peers with which a sensor can directly communicate through its wireless interface may change rapidly over time due to asynchronous sleep mode strategies, fluctuations in the radio environment, device failure or mobility. Through its wireless interface, a sensor thus connects to a communication link with undetermined connectivity properties. Sensor networks are a challenge to current IP standards, since on the one hand these protocols were designed to work on wired links and on the other hand these protocols were designed to work on machines that do not have drastic constraints in terms of CPU, power capacities, and memory, as sensor nodes do. In consequence, several key standard protocols (including TCP, UDP, DHCP, NDP, SLAAC, and OSPF) do not function correctly in this environment. Nevertheless, IPv6-based sensor networking is a viable long term goal because it would enable generic, large scale, seamless integration of millions of sensing devices using heterogeneous radio technologies, at a low cost, and in a future-proof manner. The Internet Engineering Task Force (IETF) is currently engaged into multiple efforts addressing the limitations of existing standards concerning wireless sensor IP networking. Some of the standards under construction aim at fitting IP formats, especially IPv6 formats, to direct wireless communications using low power radio technologies such as IEEE 802.15.4, which require IP format compression. Other standards in development aim at providing multi-hop wireless sensor communication with IPv6, which requires specific routing protocols, efforts in which we actively participate, prompting numerous joint publications with both industrial and academic partners.

Coloring in wireless sensor networks Graph coloring is used in wireless networks to optimize network resources: bandwidth and energy. We focus on grid topologies that constitute regular topologies for large or dense wireless networks. We consider various transmission ranges and identify a color pattern that can be reproduced to color the whole grid with the optimal number of colors. We obtain an optimal periodic coloring of the grid for the considered transmission range. We then compare these optimal results on grids with those obtained by SERENA, our a 3-hop distributed coloring algorithm, and identify directions to improve SERENA.

Coloring algorithm optimized for dense wireless networks In 2011, we also designed OSERENA "Optimized SchEduling RoutEr Node Activity", a distributed coloring algorithm optimized for dense wireless networks. Network density has an extremely reduced impact on the size of the messages exchanged to color the network. Furthermore, the number of colors used to color the network is not impacted by this optimization. We describe the properties of the algorithm and prove its correctness and termination. Simulation results point out the considerable gains in bandwidth.

WSNs operating in low duty-cycle

We have designed a cross layer protocol for surveillance Wireless Sensor Networks (WSNs) which monitor infrequent events. Thus, the power is mainly consumed in the sensing task. We show that WSNs can operate with a low duty-cycle of their transceivers (e.g. 1%) if they use the Receiver Initiated MAC protocol and an opportunistic geographic routing to deliver the packet to the sink. The main idea is that a node transmits its packet to the next awake node as long as this decreases the remaining distance to the sink. We propose three variants of the routing protocol: i) basic-opportunistic, ii) opportunistic with delay, and iii) opportunistic with backtracking. The two last variants allow a packet to be discarded or moved further away from the sink if necessary. We have evaluated the loss incurred by the low duty-cycle mechanism in terms of end-to-end packet delay. We also have evaluated the increase in transmission range brought about by the low duty-cycle approach. We have shown that opportunistic routing schemes offer much better delivery delays than shortest path routing schemes operating with a low duty-cycle for their transceivers. Moreover, we have quantified the gain in terms of energy saving that the low duty-cycle strategy based on our scheme offers over the approach where the sensors are always awake.

2.6.5 Collaborations

Hipercom's sensor network expertise has been leveraged by several companies including EDF, EADS, CNES, Sagem and Hitachi.

- Many contractual collaborations:
  - Hipercom and Sagem collaborate since 2009 on SMARTMESH, a project aiming at elaborating a novel modular sensor platform prototype for area surveillance, featuring several sensors such as infra-red camera, PIR or acoustic sensors, able to self-organize and co-operate via wireless spontaneous networking (Hipercom being in charge of the latter development).
  - Hipercom and Hitachi have recently collaborated on the evaluation and modeling of the RPL routing protocol for low-power lossy networks, in the context of a bilateral industrial contract. This activity yielded the specification of a new routing protocol, LOAD, which is currently being considered as potential standard in the IETF.
  - With Hitachi and ERDF: Study of applicability of existing sensor networking routing protocols for their particular problems in, among other things, smart-metering and smart grid maintenance. Observing that existing protocols currently in standardization were insufficient for their purposes, collaborative work on development of a (reactive) routing protocol specifically for metering and data collection were undertaken, currently in the process of standardization and finalization. The main new aspect, as compared to classic Internet routing, is that routing structures are traffic-driven. The main difference from the existing protocols in standardization for this problem domain being (i) inherent support for bi-directional traffic and (ii) shortest-paths are produced also for non-primary traffic flows.
  - OCARI2 project (industrial wireless sensor network, QoS, cross layer, energy efficiency, routing, node activity scheduling),
  - SAHARA project (wireless sensor network embedded in aircrafts),
  - SMARTMESH project (modular sensor platform prototype for area surveillance),
  - STIC INRIA-Tunisian Universities: the team of Prof. Leila Saidane at ENSI (Performance improvement in a wireless sensor network),
- Non contractual:
  - BAE (OLSRv2),
  - Freie Universitaet (sensor networks, DHT),
  - Deutsche Telekom Labs/TU-Berlin, Germany,
  - University of Athens, Greece.

2.6.6 External support

- OCARI2 project (industrial wireless sensor network, QoS, cross layer, energy efficiency, routing, node activity scheduling),
- SAHARA project (wireless sensor network embedded in aircrafts),
- SMARTMESH project (modular sensor platform prototype for area surveillance),
- ERDF (smart metering),
- STIC INRIA-Tunisian Universities: the team of Prof. Leila Saidane at ENSI (Performance improvement in a wireless sensor network).

2.7 Objective 4: Mobile and vehicular applications

2.7.1 Executive summary

Military and vehicular ad hoc networks are two examples of wireless networks dealing with mobility and for which specific frequency bands have been assigned.

In 1999, the US Federal Communication Commission allocated 75 Mhz in the 5.9 GHz band for vehicular communications: Dedicated Short Range Communications (DSRC). This event and the existence of the IEEE 802.11 standard open the door to the development of Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure communications in Vehicular ad hoc Networks (VANETs). First, we have studied how OLSR can manage these VANETs. We found that MultiPoint Relays (MPRs) are not completely satisfactory in these networks because of the high mobility and the overhead incurred. Thus, we propose to use opportunistic routing. The scheme we design is based on an active signaling technique embedded in the acknowledgement packet. We show the optimality of this technique by simulation.

VANETs are a special case of MANETs, networks considered as the best candidate for military tactical networks. Ad Hoc tactical networks are evolving towards a variety of applications with different Quality of Services, different data rates, and various latency constraints. Services can be point-to-point or point-to-multipoint. One major challenge is to guarantee interoperability between mobile terminals built by different manufacturers. That is why standardized interfaces and protocols are needed. These mobile terminals operate in networks whose deployment can be ruled at national and/or coalitional level. Hence, quick autoconfiguration and merge procedures are required. That is why the HIPERCOM project-team focused on:

- quality of service support,
- OLSRv2: a modular, extensible and more efficient version of OLSR,
- multicast,
- autoconfiguration,
- hierarchical routing.

All these protocols, except hierarchical routing, have been implemented and demonstrated on the DGA/MI MANET platform including 18 wireless nodes.

2.7.2 Personnel

Cédric Adjih, Ichrak Amdouni, Emmanuel Baccelli, Skander Banaouas, Thomas Clausen, Philippe Jacquet, Erwan Livolant, Salman Malik, Amina Naimi Meraihi, Yacine Mezali, Pascale Minet, Paul Mühlethaler, Ridha Soua Yasser Toor.

2.7.3 Project-team positioning

NRL, CRC, DARPA are our main competitors for military tactical networks. Military companies like Thales and BAE are also very present in this domain with research groups publishing in military and civilian conferences. Concerning vehicular networks, there are a lot of reserach groups in Europe, Japan and USA working on this topic. In Europe, Germany has very strong teams in this domain.

Again, the peculiarity of HIPERCOM lies in the modeling, protocol design, performance evaluation and protocol implementation.

2.7.4 Scientific achievements

a) Protocols for military tactical networks

a1) QoS support We have shown that the search of a good path for a new connection that does not destroy the quality of service of existing connections is an NP-hard problem. The result is independent on how the bandwidth nodes interfer as long they interfer at least on one hop. In this area, one contribution was the definition and testing of an efficient reservation algorithm bandwidth reservation, respecting wireless network constraints. A second contribution is more accurate computation of remaining link bandwidth by considering bandwidth on other links multiplied by the average packet retransmission on this link (inverse of packet successful transmission rate).

We have also proposed a solution called QoS-OLSR that enhances OLSR with Quality of Service support. This solution, taking radio interferences into account, ensures that QoS flows, if accepted by the admission control, will receive a bandwidth close to this requested. We have shown that routes avoid the congested links in the wireless network. This solution has been implemented on the MANET/OLSR demonstrator of DGA/MI (MoD).

We worked with military manufacturers to define an architecture of QoS taking into account the specificities of military tactical networks: new MAC and physical layers, higher radio range and lower data rate, specific TDMA or CSMA.

a2) OLSRv2 An automated node installation and management software was developped at INRIA Rocquencourt and used to deploy testbeds (including the one at DGA/MI) and perform measurements. For DGA/MI, we have first developped a link selection based on the power of the signal received. We have then implemented OLSRv2 on the wireless nodes of the DGA/MI testbed. This implementation has been validated through extensive tests with various topologies including mobile ones.

a3) Multicast For DGA/MI, we have compared three multicast protocols: SMOLSR a broadcast throught the whole network optimized by multipoint relays, MOLSR a tree based at the source and MOST, an overlay tree reaching only the clients of the multicast group. We have implemented SMOLSR and MOST on top of the OLSRv2 DGA/MI testbed. We have measured the loss rate and delays for video flows and audio flows. MOST appears to be very good for networks with groups having a small number of clients or networks that are not dense. For audio flows, it provides a quasi null error rate and a delay less than 5 ms with the 802.11g MAC. This can be explained by its use of unicast transmissions. Unicast benefits from higher data rates, automatic rate adaptation and reliability features such as acknowledgement and retransmissions. SMOLSR and MOST are more resilient to topology changes and mobility.

a4) Autoconfiguration We have designed and developed AUTOLSR, the autoconfiguration of a MANET using the OLSR routing protocol. This autoconfiguration protocol is able to:

- support several independent MANETs,
- provide a unique address within a MANET,
- provide a unique global address,
- support MANETs merges.

AUTOLSR uses a smart detection of address conflicts based on node identifiers and the addition of small annotations in OLSRv2 messages. It also includes a sophisticated IPv6 prefix management for merging, for distributed prefix selection and for global connectivity. It is implemented for OLSRv2 and is running on the DGA/MI testbed.

a5) Hierarchical routing We also designed L-OLSR (for Layered OLSR), an extension of OLSR that manages a hierarchy of links. A preference value is assigned to each link, depending on its characteristics. The L-OLSR routing uses as much as possible the preferred links. The applications of such a routing are numerous:

- Support of fast mobility. In a wireless network, where some nodes move fast, whereas others remain static, links between static nodes are preferred to links between a static and a mobile node, which are preferred to links betwwen two mobile nodes.
- Network merge. L-OLSR presents the advantage of not modifying the routing after amerge of two wireless networks, provided that the links intra-network are preferred over links inter-networks.

b) Protocols for vehicular networks

We have achieved numerous studies and design of protocols for vehicular networks and more spefically for V2V (Vehicle-to-Vehicle) network.

First we have studied the channel occupancy induced by the OLSR proactive routing protocol used in a linear Vehicular Ad hoc Network (VANET). Unlike previous studies, which usually use simulations to evaluate the overhead, we have proposed a simple analytical model to carry out this evaluation. Moreover, we did not evaluate the total overhead induced by the routing protocol as is usually proposed, but, for a given node, the channel occupation induced by the routing protocol.

We have studied flooding techniques for safety applications in VANETs. The typical scenario is the diffusion of an alert message after a car crash in a platoon of vehicles. The packet is diffused with the pure flooding, the multipoint relay (MPR) diffusion of OLSR and a geographic aware protocol. For OLSR we have introduced a variant (Robust-MPR) to improve the reliability. Different realistic scenarios were considered and various parameters such as vehicle density, and background traffic load were scrutinized. We have shown that the Robust-MPR and the geographic aware protocol satisfy the requirements of the safety applications while using considerably less overhead than pure flooding.

We have shown that the geographic aware protocols can be improved for the diffusion of an alert message by using opportunistic routing. We have designed OB-VAN (Opportunistic Broadcast for VANets) a new protocol that uses this idea. One of the novelty of this protocol is the use of an active signalling technique in the acknowledgement procedure to select the best relay taking advantage of the reception pattern of each message. We have studied OB-VAN in a linear VANET and have shown that it outperforms the flooding for the delay and the amount of overhead. However the delivery ratio of OB-VAN may be insufficient for safety applications. This remark has led to the design of R-OB-VAN which is a reliable variant of OB-VAN. With extensive simulations, we have shown that

R-OB-VAN maintains a high delivery ratio even in the presence of packet loss due to shadowing.

We have studied the performance of the Aloha scheme in linear VANETs. This analysis assumes a SINR (Signal over Interference plus Noise Ratio) based model. In this model, we have derived the probability of a successful transmission between two vehicles at a distance of R meters. We have also computed the mean throughput according to Shannon's law. In these two models, we have optimized the two quantities directly linked to the achievable network throughput i.e., the mean packet progress and the density of transport.

Finally, we have studied the utilization of opportunistic routing and shown that this technique is also beneficial for point to point traffic. It decreases the delay and increases the throughput compared with shortest path first routing. Moreover, we have also shown that opportunistic routing for point to point traffic eases considerably the optimization of the MAC scheme e.g. the transmission probability for Aloha and the carrier sense threshold for CSMA.

2.7.5 Collaboration

We collaborate with the INRIA IMARA project-team on geographic routing.

2.7.6 External support

We received support from MoD for this activity.

3 Knowledge dissemination

3.1 Publications

	2008	2009	2010	2011
PhD Thesis	1	3	1	3+2 in Feb & March 2012
H.D.R (*)				1
Journal	6	12	9	7
Conference proceedings (**)	16	33	33	24
Book chapter	1	4		
Book (written)				3
Book (edited)				
Patent				
General audience papers	3		19	20
Technical report	13	16	19	18
Deliverable				

(*) HDR Habilitation à diriger des Recherches

(**) Conference with a program committee

Major journals

- IEEE Communication Surveys and Tutorials: 2
- IEEE Journal on Selected Areas in Communications: 2
- IEEE Transaction on Industrial Electronics: 1
- IEEE Transaction on Information Theory: 1
- Computer Communications: 2

- Computer Networks: 2
- ACM International Journal of Network Management: 1
- Journal on Wireless Communication and Networking: 1
- Real-Time Systems Journal: 1
- Future Internet: 2
- International Journal of Computer Science Issues : 2

Major conferences

- INFOCOM: 5
- GLOBECOM: 2
- PIMRC: 2
- International Symposium on Information Theory: 2
- MobiHoc: 2
- WiMob: 2
- Wireless Days: 8
- WMNC: 3
- WCNC: 5
- IWCMC: 7
- VTC: 4
- European Wireless: 3
- MedHoc Net: 4
- LCN: 2
- ICC: 1
- ITST: 5
- AdHoc Now: 1
- AofA: 1
- WiOpt: 1
- AINA: 2
- ICN: 2
- MASS: 1
- WoWMoM: 1
- QoSim: 1
- DCOSS: 1

3.2 Software

OLSR pre-v1 (corresponding to draft 3, draft 5, draft 7 of the OLSR routing protocol)
. A-2 . S-4 . SM-2 . EM-1 . SDL-3
One of the very early versions of OLSR (used for experimentation, and publically diffused) predating RFC 3626.

OOLSR / IOLSR / miscellaneous tools and support for OOLSR
. A-3 . SO-4 . SM-2 . EM-1 . SDL-3 and SDL-4
The implementation of OLSR compliant with RFC 3626, and also with numerous extensions (security, quality of service, route exchange, ...)

MOLSR / SMOLSR / MDFP (extension of OOLSR for MOLSR and SMOLSR - multicast)
. A-2 . SO-4 . SM-2 . EM-1 . SDL-4
A derivative from OOLSR, implementing Multicast routing for OLSR (MOLSR protocol), and Simple-Multicast OLSR (MPR flooding). Also an independent module MDFP performs encapsulation of application packets.

QSR (extension to OOLSR for quality of service)
. A-1 . SO-4 . SM-2 . EM-1 . SDL-3
A derivative from the MDFP module, for quality of service routing (used along with OOLSR which also integrates QoS routing).

QOED (extension of OOLSR for interoperability with OSPF)
. A-2 . SO-4 . SM-2 . EM-1 . SDL-3
A "bridge" that allows interoperability with OSPF ; QOED exchanges routes between Quagga (an existing free software OSPF+other protocols) and OOLSR.

QoSOLSR-NS2 (extension of QoSOLSR, an extension of OLSR providing a quality of service support that is interference aware)
. A-1 . SO-4 . SM-2 . EM-1 . SDL-1
A version of the simulator NS-2 with another implementation of OLSR (not OOLSR), with quality of service support.

NCTools (Tools for network coding)
. A-1 . SO-4 . SM-1 . EM-1 . SDL-1
Misc. tools used for evaluation and simulation of Network Coding (protocol DRAGONCAST, min-cut max-flow for hypergraphs (wireless model), linear program for optimal broadcast packet rate calculation . . .).

OPERA/OCARI: a suite including EOLSR an energy efficient routing based on OLSR and OSERENA a node activity scheduling based on node coloring for the OCARI stack designed for a wireless sensor network in industrial environment;
. A-4 . SO-4 . SM-2 . EM-3 . SDL-3
An implementation of a OPERA (network part of OCARI), implementing EOLSR (through neighborhood discovery with Hello messages and tree building by means of STC messages), and OSERENA (optimized node coloring).

MPRCalc: A tool used for simulation and evaluation of performance of various flooding algorithms:
. A-1 . SO-4 . SM-1 . EM-1 . SDL-1
This implementation includes miscellaneous computations of MPR (MultiPoint Relays) and connected dominating sets.

Multicast MOST: a multicast protocol for MANET based on an overlay spanning tree.

. A-3 . SO-4 . SM-1 . EM-2 . SDL-3

A derivative of MOLSR, implementing a different multicast protocol: MOST MOLSR is based on a multicast tree rooted at the source, whereas MOST is a Multicast Overlay Spanning Tree. MOST provides a higher throughput and a higher delivery rate than MOLSR, because of the use of point-to-point messages that are acknowledged. Three versions have been developed.

- one based on OLSRv1 and used in a demonstration with NATO.
- a second one with a centralized server, developed in an ADT (Action de Developpement Technologique)
- a third one for OLSRv2 and IPv6, installed at DGA/MI.

pyOLSR

. A-1 . SO-2 . SM-1 . EM-1 . SDL-4

An implementation of the OLSR RFC 3626 written in Python http://hipercom.inria.fr/pyOLSR/ (was mostly used to check the RFC 3626).

AdHocNodeManager

. A-2 . SO-2 . SM-2 . EM-2 . SDL-3

A tool used to manage Ad Hoc Nodes, with a web interface, and an internal protocol, and that allows to start/stop/restart/configure/log/represent the state of the nodes (wirelessly). This is an invaluable tool for people in charge of real MANETs testbeds. We used it intensively on the DGA/MI testbed with 18 nodes.

AdHocGKA

. A-1 . SO-4 . SM-1 . EM-1 . SDL-1

(1450 lines) http://hipercom.inria.fr/AHGKA/ An implementation of a group-key aggrement, designed for wireless networks.

EOLSR+Serena implementation in Java

. A-1 . SO-4 . SM-1 . EM-1 . SDL-1

An implementation of the network part of OCARI in Java: most of EOLSR routing and coloring protocol SERENA, with the API of OCARI. This has been used in the ANR OCARI project to prove the feasibility of the integration of the network layer developed by INRIA and the MAC layer developed by LIMOS and LATTIS.

MPR-OSPF:

. A-1 . SO-4 . SM-2 . EM-1 . SDL-1

It implements the OSPF extension to support ad hoc networking. It is RFC 5449 compliant. Implementation in C code.

P2P-RPL: Reactive discovery of point-to-point routes in low power and lossy networks.

. A-1 . SO-4 . SM-1 . EM-1 . SDL-1

This implementation is draft-ietf-roll-p2p-rpl-07 compliant. Based on the Contiki operating system. Implementation in C code.

muOLSR: a small OLSR implementation for wireless sensor networks (Scatterweb).

. A-1 . SO-4 . SM-1 . EM-1 . SDL-1

Implementation in C code on Scatterweb wireless sensor nodes.

EY-NPMA model for ns-3

. A-1 . SO-4 . SM-1 . EM-1 . SDL-1

An implementation of medium access EY-NPMA (from the Hiperlan standard) for the simulator ns-3.

3.3 Valorization and technology transfert

- Within our four successive contracts with DGA, we have demonstrated the advantages of OLSR by theoretical models, simulation and measures performed on a real testbed. The deliverables we wrote have been given to military industrial partners (Sagem, Thalès...). We made four presentations at NATO dealing with OLSR, multicast, QoS support... As a result, OLSR has been implemented in several military networks and is included in several standardization proposals.
- The OPERA suite for the OCARI stack designed for wireless sensor networks in industrial environment. This suite includes EOLSR, an energy efficient routing protocol and SERENA a node activity scheduling based on node coloring. Initially designed in an ANR project coordonated by EDF, the OCARI stack was integrated during the year 2011, fruit of the collaboration between INRIA, LIMOS, TELIT and EDF. An OCARI alliance is being formed to widespread the OCARI use and ensure its perennity.

3.4 Teaching

Philippe Jacquet taught:

- class : Mobile networking (Polytechnique),
- class: Telecommunication. Master COMASIC (Polytechnique)

Emmanuel Baccelli taught:

- class : Mobile networking at Ecole Polytechnique.

Pascale Minet taught:

- Networks and quality of service in Master Systèmes Electroniques et Traitement de l'Information, at INSTN (Saclay).
- Mobile ad-hoc networks: medium access, routing and quality of service in Master Ingénierie informatique of the university of Marne-la-Vallée.
- Mobile ad hoc networks and wireless sensor networks: medium access, routing and energy efficiency in Master ScTIC (Systèmes complexes, Technologies de l'Information et du Contrôle) of the University of Paris 12.

Khaldoun Al Agha, Lila Boukhatem, Steven Martin, Lin Chen and Tara Ali-Yahia are teachers at the Computer Science department and IUT of Paris-Sud university. They teach every year:

- in the M2R Informatique MASTER (University of Paris-Sud), classes: Mobile networks, Broadband networks
- in L1, L3, M1, M1 Miage, M2 Professionnel and CCI MASTERS (University of Paris-Sud), classes: Networks architecture, Telecommunication, Mobile networking, Security.
- in Ingé1, Ingé2 and Ingé3 levels (IFIPS - Institut de de Formation des Ingénieurs de la faculté Paris-Sud), classes: Networks architecture, Telecommunication, Mobile networking.

3.5 Standardization

The HIPERCOM project plays an important part in the standardization process. More precisely, it is active at:

- IETF in the following working groups:
  - AUTOCONF: T. Clausen is chairman and E. Baccelli is an important contributor, co-authoring an RFC and multiple Internet Drafts;
  - MANET: see the numerous contributions of T. Clausen, P. Jacquet, U. Herberg, co-authoring multiple RFCs and multiple Internet Drafts.
  - OSPF: E. Baccelli, T. Clausen and J.-A. Cordero Fuertes are important contributors, co-authoring one RFC and multiple Internet Drafts;
  - ROLL: E. Baccelli and T. Clausen are important contributors in this working group, co-authoring one RFC and multiple Internet Drafts.
- IEEE: HIPERCOM has pending patents with regard to 802.11;
- ETSI: Philippe Jacquet is the INRIA official contact;
- Car2Car: Paul Mühlethaler is the INRIA official contact;
- NATO: Pascale Minet made four presentations about OLSR and its extensions.

3.5.1 OLSRv2 Standardization

In 2003, the IETF published OLSR as RFC3626. In 2005, the IETF decided that time had come to advance OLSR from Experimental RFC onto Standards Track, and so, the Hipercom team once again swung into action and OLSRv2 saw the light of day. Based on the same algorithms and ideas as OLSR contained in RFC3626, OLSRv2 builds on the experience gained by a wide community from tests and deployments over the years since RFC3626, and features a more modular and extensible architecture, while being simpler and more efficient than its predecessor.

Standardization is progressing, and we are organizing annual Interop/Workshops, specifically for implementors of OLSRv2 and its constituent parts. Being modular, by design, OLSRv2 is made up from a number of generalized building blocks, standardized independently and applicable also for other MANET protocols. As of 2012, RFC5148 - Jitter Considerations in Mobile Ad Hoc Networks, RFC5444 - Generalized MANET Packet / Message Format, RFC5497 - Representing Multi-Value Time in Mobile Ad Hoc Networks (MANETs), and RFC 6130: MANET Neighborhood Discovery Protocol (NHDP) are published as RFCs, while OLSRv2 is in the final phases of standardization. There are also some new developments inside the IETF on security with several I-Ds published, one undergoing IESG review for publication as RFC in 2012.

As with OLSR (RFC3626), OLSRv2 is being edited by Thomas Clausen (Hipercom@LIX), with contributions from the rest of Hipercom, and from industrial and academic partners world-wide.

The implementation and experimental efforts are being lead by Ulrich Herberg (Hipercom@LIX).

3.5.2 Ad hoc IP Autoconfiguration

One of the assumptions, often brought forward when discussing MANETs is, that they're self-organizing and that a pre-determined infrastructure cannot be assumed present to ensure correct operation.

For this to hold true, routers in a MANET must be able to self-configure with their necessary interface parameters – notably, they must be able to acquire suitable and unique prefixes for assigning addresses to hosts, associated to a MANET router. In the dynamic environment of a MANET, this presents a quite unique challenge.

The IETF AUTOCONF working group, chartered in the fall of 2005 with the task of developing MANET autoconfiguration protocols for IPv6. The working group is co-chaired by Thomas Clausen (Hipercom @LIX), and Emmanuel Baccelli is an important contributor, co-authoring multiple Internet drafts in this realm and RFC5889: IP Addressing Model in Ad Hoc Networks.

3.5.3 Wireless mesh OSPF

OSPF does not work 'as is' on mobile ad hoc networks. OSPF's trademark as a generic Internet routing solution is thus somewhat endangered by the emergence of MANETs.

Since 2005, the IETF is addressing this novelty and working on the standardization of an extension of OSPF for mobile ad hoc networks. Hipercom of course actively participates in this process, since it builds up on MANET experience with proactive routing, and thus OLSR-derived techniques.

We considered a wireless extension for OSPF based on OLSR (RFC3626), the MANET proactive protocol that has emerged as the simplest and most robust solution for mobile ad hoc routing.

This extension has been published as RFC5449 - OSPF MPR Extension for Ad Hoc Networks and defines an OSPFv3 MANET interface type, allowing OSPFv3 deployments including also areas with MANET characteristics.

Hipercom's OSPF standardization effort is being lead by Emmanuel Baccelli.

The implementation and experimental efforts are being lead by Juan Antonio Cordero Fuertes (Hipercom@LIX).

3.5.4 Routing in the Internet of Things

Current standard IP protocols are challenged by the stringent (memory, CPU, power) constraints experienced on tiny devices such as sensors, actuators and other devices of the Internet of Things. Since 2008, the IETF is addressing this new challenge in several working groups including ROLL, which is standardizing routing and dissemination protocols for such environments.

Hipercom has been actively invovled in ROLL since 2009. Emmanuel Baccelli and Thomas Clausen co-authored several Internet Drafts specifying new routing solutions (P2P-RPL, LOAD) in this realm, as well as RFC6206: The Trickle Algorithm.

The implementation and experimental efforts are being lead by Matthias Philipp (Hipercom@LIX).

3.6 Visibility

3.6.1 Conference organization, programm committee and editorial board

- **Cédric Adjih, Philippe Jacquet, Pascale Minet and Paul Muhlethaler** have been recognized as experts for reviewing military ad hoc network proposals submitted to DGA.

- **Pascale Minet** was co-chair of RTNS 2008, the 16th international conference on Real-Time and Network Systems, held in Rennes in 2008.
- **Pascale Minet** was also Guest editor of the Real-Time Systems Journal in 2009.
- **Philippe Jacquet** was the PC chairman of the AofA conference, held in Juan-les-Pins, in June 2008. This conference was organized by INRIA.
- During the Workshop Fundamentals of Communications and Networking, organized by Bell Labs and INRIA in November 2009 at Rocquencourt, Pascale Minet gave a presentation entitled "Energy efficiency in wireless sensor networks: node activity scheduling".
- **Paul Mühlethaler** has organized the DGA/INRIA workshop on Telecommunications in March 2009
- **Organization of MobiHoc 2011**, the Twelfth ACM International Symposium on Mobile Ad Hoc Networking. The HIPERCOM project contributed to the great success of this international conference held in Paris in May 2011. Philippe Jacquet served as General Chair, Christine Anocq as Local Arrangement Co-chair, Thomas Clausen as Finance Co-chair, Paul Muhlethaler, Anis Laouiti and Pascale Minet as Workshop Co-chairs, Emmanuel Baccelli as Registration Chair, Cédric Adjih as Web Chair.
- **Aline Carneiro Viana** was invited as a speaker at the GBR 2011, Beyond Networking workshop, Buzios, Rio de Janeiro, Brazil. October 2011.
- **Contribution to the OCARI shows**. Pascale Minet, Cédric Adjih, Ichrak Amdouni and Ridha Soua were active contributors as well as LIMOS, TELIT and EDF to the two OCARI shows organized by EDF. The fist one in September was given for EDF executives. The second one in December was larger. Invited people came from government agencies and industries. The goal was to prove the feasibility of an OCARI wireless sensor network in industrial environments, focusing on time constrained traffic and energy efficiency. During the ETSI M2M workshop, organized by ETSI in October 2010 at Sophia, Pascale Minet and Tuan Dang (EDF) presented a poster summarizing the results obtained in the OCARI project. Furthermore, at the L2I workshop organized by LIMOS, University of Clermont-Ferrand, in June 2010, she gave a presentation entitled "Bénéfices du cross-layering sur le coloriage dun réseau sans fil", based on the work of INRIA in the OCARI project
- **Organization of OLSR Workshop and Interop** Emmanuel Baccelli and Thomas Clausen contributed to the OLSR Workshops and Interop held in:
  - 2008 (Ottawa)
  - 2009 (Vienna).
- **Cédric Adjih** contributed to the DUMBO 2 demonstration in 2008 in Thailand, proving the feasibility of OLSR in heterogeneous networks including nodes embedded in ships.

Pascale Minet was member of the program committee of:

- ASEA 2009, International Conference on Advanced Software Engineering & Its Applications,November 2009.
- AdHocNets 2011, Third International ICST Conference on Ad Hoc Networks, September 2011.
- CFIP 2011, Colloque Francophone sur l'Ingnierie des Procoles, May 2011.
- CIT 2011, 11th IEEE International Conference on Computer and Information Technology, September 2011,
- DCNET 2011, International Conference on Data Communication Networking, July 2011,
- ECRTS 2010, 22nd EUROMICRO Conference on Real-Time Systems, July 2010.
- GlobeCom 2011 Workshop HeterWMN, December 2011.
- HPCC 2010, International Conference on High Performance Computing and Communications, June 2010.
- ICCCN 2008, International Conference on Computer Communications and Networks, August 2008.
- ICETE 2010, International Joint Conference on e-Business and Telecommunications, July 2010.
- ICN 2011, the 10th International Conference on Networks, January 2011.
- IFIP Wireless Days 2011, October 2011.
- IUCC 2011, the 10th IEEE International Conference on Ubiquitous Computing and Communications, August 2011.
- IWCMC 2011, the 7th International Wireless Communications and Mobile Computing Conference, July 2011.
- Med-Hoc-Net 2011, 11th IEEE/IFIP Mediterranean Ad-Hoc Networking conference, June 2011.
- PAEWN 2010, Int. workshop on Performance Analysis and Enhancement of Wireless Networks, April 2010.
- RTNS 2011, 18th International Conference on Real-Time and Network Systems, September 2011.
- SERA 2011, Int. Conf. on Software Engineering Research & Applications, August 2011.
- SNPD 2011, 10th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, June 2010.
- SPECTS 2011, International Symposium on Performance Evaluation of Computer and Telecommunication Systems, July 2011.
- WINSYS 2010, International Conference on Wireless Information Networks and Systems, July 2010.

Pascale Minet was also reviewer for the following journals:

- IEEE/ACM Transactions on Networking,
- IEEE Transactions on Industrial Informatics,
- IEEE Transactions on Vehicular Technology,
- IEEE Transactions on Wireless Communications,
- Real-Time Systems Journal,
- International Journal of Communication Systems,
- Computer Communications Journal.
- Ad Hoc Networks journal.

Philippe Jacquet belongs to the editorial board of the DMTCS journal.

Paul Mühlethaler was reviewer for the following journals and international conferences:

- IEEE ITS Magazine,
- IEEE/ACM Transactions on Networking,
- IEEE Journal on Selected Areas in Communications,
- WINET ACM Wireless Networks journal,
- ISCIS,
- ISIT,
- VTC spring;

Since July 2010, **Paul Mühlethaler** is scientific head of the DGA/INRIA partnership. Paul Mühlethaler is an expert by the European Community for telecommunication projects.

Cédric Adjih was a co-chair for ACM MOBIHOC 2011. He was also:

- Member of the program committee of IEEE GLOBECOM 2010, December 2010.
- Member of the program committee of AINTEC 2011, *7th Asian Internet Engineering Conference*, November 2011.
- Reviewer for the journal *ACM Transactions on Sensor Networks*
- Reviewer for the MILCOM 2011, *IEEE Military Communications Conference*, November 2011.

Cédric Adjih served also as reviewer for the French ANR (for proposals for the *Young Researchers* program).

Emmanuel Baccelli was a co-chair for ACM MOBIHOC 2011, and is currently TPC for IEEE SECON, IEEE PerGroup, ACM MobileHealth and NovaEnv. He also served as:

- expert reviewer for the french National Research Agency (ANR) in 2011.
- member of the technical program committee for PerCom 2010,
- reviewer for IEEE GLOBECOM 2010.

Aline Carneiro Viana served as:

- Local arrangement co-chair of ExtremeCom 2011: *3rd Extreme Conference on Communication*, Manaus, Brazil. September 2011.
- Publicity chair of ExtremeCom 2011: *3rd Extreme Conference on Communication*, Manaus, Brazil. September 2011.
- TPC co-chair of Shadow ACM Conext 2011: *Shadow ACM 7th International Conference on emerging Networking EXperiments and Technologies.* Shadow TPC meeting was in Toronto, Canada. August 2011.
- Publication chair of AdHocNets 2011: *3rd International ICST Conference on Ad Hoc Networks*, paris, France. September 2011.

She also served in the program committees for the following conferences/workshops:

- Mobility 2011: *1st International Conference on Mobile Services, Resources, and Users*, Barcelona, Spain. October 2011.
- WOCN 2011: *IEEE International Conference on Wireless and Optical Communications Neworks*, Paris, France. May 2011.
- WPerformance 2011: *Workshop em Desempenho de Sistemas Computacionais e de Comunicacao*, Natal RN, Brazil. Julho 2011.

She has been also performing remote evaluation of short proposals for the EC ”Future and Emerging Technologies” programme (EC FET-Open).

Ichrak Amdouni gave a presentation entitled *Energy Efficiency and Routing in the OCARI project*, in les Journées thématiques Rescom : Réseaux de Capteurs et leurs applications - Etat de l'art et transfert technologique, 19-20 Oct. 2011, Université Pierre et Marie Curie.

Khaldoun Al Agha was member of the program committee for:

- IEEE Wireless Communications & Networking Conference,
- IASTED International Conferences on Wireless Communications (WC),
- IFIP Networking,
- IFIP Mediterranean Ad Hoc Networking Conference (Med-Hoc-Net),
- IFIP/IEEE Wireless days.

Lila Boukhatem was member of the program committee:

- IEEE InVeNet 2010,

- IEEE International Workshop on Intelligent Vehicular Networks,
- IFIP/IEEE Wireless days.

Lin Chen participates to the program committee of:

- Conference on Decision and Game Theory for Security 2010.

3.6.2 PhD thesis Jury

Pascale Minet was member of the Gilles Kahn 2011 jury awarding an excellent 2010 PhD thesis in Computer Science.

Pascale Minet was reviewer of the PhD Thesis of:

- Bilel Nefzi, PhD thesis of the Institut National Polytechnique de Lorraine, September 2011.
- Nancy El Rachkidy, PhD thesis of the Université Blaise Pascal, December 2011.
- Arnaud Kaiser, PhD thesis of the Université Paris XIII, December 2011l.
- Wahabou Abdou, PhD Thesis of the Université de Franche-Comté, December 2011.
- Azza Jedidi, University of Rennes, November 2010.
- Bashir Yahya, University of Versailles SaintQuentin, November 2010.
- Patrick Sondi Obwang, University of Valenciennes and Hainaut-Cambresis, December 2010.
- Noureddine Kettaf, Université de Haute-Alsace, Colmar, May 2008.
- David Espes, Universite Paul Sabatier, Toulouse, November 2008.
- Sébastien Linck, Université de Franche-Comté, Montbéliard, December 2008.
- Damien Masson, Université de Paris-Est, Marne-la-Vallée, December 2008.

She was Jury member for the Habilitation à Diriger des Recherches of:

- Laurent George, University of Nantes, November 2008.
- Anthony Busson, University of Paris Sud 11, December 2011.

She was Jury member of the PhD Thesis of:

- Karima Malaoui, ENSI, Tunis, December 2009.
- Inès Korbi, ENSI, Tunis, December 2009.
- Teck Aguilar, Telecom & Management SudParis, University of Paris 6, December 2010.

She was chairperson of the jury for the PhD Thesis of:

- Gérard Chalhoub, Université Blaise Pascal, Clermont-Ferrand, December 2009.
- Mohamed Riadh Kortebi, Université d'Evry, January 2009.
- Amel Hamdi, University of ParisSud 11, December 2010.

Paul Mühlethaler was reviewer for the habilitation thesis of Lila Boukhatem "Mobilités et Gestion de Ressources" (December 09) and jury member for the habilitation thesis of Sidi-Mohammed Senouci "New protocols to control light infrastructure networks (Nouveaux protocoles pour la maitrise des réseaux à infrastructure légère)".

Aline Carneiro Viana served as a reviewer for the PhD committee of Natascia Piroso, Sapienza University of Rome, Italy.

4 External Funding

The following table summarizes the budget allocated to our project-team in keuros coming from our main contracts.

(k euros)	2008	2009	2010	2011
INRIA Research Initiatives				
ADT Inria MOBSIM				
National initiatives				
ANR OCARI	50	36	50	
ANR SARAH	50	53		
SYSTEM@TIC MOBISIC	100	120	45	32
SYSTEM@TIC E-COMPAGNON		54	34	
SYSTEM@TIC RAF	80	152		
SYSTEM@TIC SMARTMESH		27		23+46
FUI SAHARA				
Grand Emprunt FIT				
DIMLSC SWAN				9
DIMLSC ACRON				1
European projects				
FP7 OPNEX	65	66	66	47
ITEA2 EXPESHARE	30	30		
EDA ETARE		49	98	16
Associated teams				
Macquarie University (Australia) (B. Mans)	9		15	10
Industrial contracts				
MANETs DGA/MI CELAR	150	150	100	
OCARI2 EDF				40
Scholarships				
PhD *				
Post Doc*				
AI+				
ODL#				
Other funding				
STIC Tunisia ENSI (L. Saidane)	5	2	5	5
Total				

∗ other than those supported by one of the above projects
+ junior engineer supported by INRIA
# engineer supported by INRIA

ARCs

NC2

The NC2 project aims at enabling collaborations between French and foreign researchers working in the area of computer science and information theory. The objective is to design new optimized solutions for data transmission on shared medium networks. The expected developed research works aim to combine data information using network coding approach.
Partners: L2S; INRIA; MIT (USA) ; AUTH (Greece).

MOBSIM

MOBSIM is an ADT Action Technology Development of Inria. It aims at developping the NS3 simulation tool. The HIPERCOM team focuses on routing proto-

cols and MAC protocol (namely the EY-NPMA protocol Elimination Yield Non-Preemptive Multiple Access). An engineer has been recruited for this project.
Partners: Inria Sophia, Inria Genoble, Inria Rocquencourt.

National initiatives

OCARI

The OCARI (Optimization of Ad hoc Communications in Industrial networks) project, funded by ANR, deals with wireless sensor networks in an industrial environment. It aims at responding to the following requirements which are particularly important in power generation industry and in warship construction and maintenance: Support of deterministic MAC layer for time-constrained communication, Support of optimized energy consumption routing strategy in order to maximize the network lifetime and Support of human walking speed mobility for some particular network nodes, (e.g. sinks). The INRIA contribution concerns more particularly energy efficient routing and node activity scheduling.
Partners: EDF (coordinator), DCN, TELIT, LIMOS (Clermont Ferrand university), LATTIS (Toulouse university), LRI (Paris Sud university) and Inria.

SARAH

The SARAH project, Service Ad hoc/Filaires: Developpement d'une Architecture de Reseau Integre, is an ANR project. It aims at developing an integrated architecture of network. It started in 2007.
Partners: ALCATEL, FT R&D, LIP6, LRI, LSIIT, LSR-IMAG, SNCF, ENST, INRIA.

MOBISIC

The MOBISIC project belongs to the competitiveness cluster SYSTEM@TIC PARIS-REGION. It aims at designing and experimenting a modular system (Plug & Play), scalable adapted to events securing and local crisis management.
Partners: THALES, ALCATEL, SAGEM, GEMALTO, BERTIN Technologies, EVITECH, SINOVIA, SODERN, CEA, INRIA.

E-COMP@GNON

E-comp@gnon is a System@tic project. The goal is the realization of a new type of multimedia terminal, enhanced with wireless ad hoc IP connectivity based on the OLSR protocol.
Partners: Archos, SCNF, Telecom SudParis, DGE, Deveryware.

RAF

The RAF project, Réseaux ad hoc A Forte efficacicité belongs to the competitiveness cluster SYSTEM@TIC PARIS-REGION. It aims at designing self configuring ad hoc networks using reservation based access protocols using both time and frequency multiplexing. The project has three components : the study of ad hoc networks using a smart relaying function at the Phy/MAC level, the study and design of protocols for ad hoc networks solving simultaneously the access problem using reservation based techniques and the relaying issue for multi hop communication, the realization of a prototype using the IEEE 802.16e (WiMAX Mobile) technology.
Partners: Thales, Alcatel Lucent, EADS, IEF, INRIA, LRI, Sagem DS, and Supelec.

SMARTMESH

SMARTMESH is a System@tic project, focused on the design of intelligent wireless

sensor mesh networking for video surveillance and intrusion alarm systems.
Partners: SAGEM, CEA, Telecom SudParis, Tunecharger, Ineo, Orelia, Prodomo.

SAHARA

SAHARA is a FUI project aiming at designing a wireless sensor network embedded in an aircraft. It will make possible the wireless communications of non-critical data in an aircraft, getting rid of many aircraft cabling problems. This wireless sensor network should neither disturb the aircraft systems, nor be disturbed by them. Difficulties to meet the requirements of aeronautic and aerospatial applications come from:
1) the expected performance in throughput, energy autonomy, end-to-end delays, reliability and safety.
2) the integration of new functions in existing technology components.
3) the environment constraints (electromagnetic compatibility, temperature, vibrations, obstacles).
Partners: EADS, Astrium, BeanAir, Eurocopter, GlobalSys, Oktal, Reflex, Safran, CNES, ECE, EPMI, INRIA, LIMOS.

FIT

The HIPERCOM project-team started the development of a testbed for SensLab in 2010. This testbed located in building 21 at Rocqquencourt INRIA center consists now of 40 wireless SensLab nodes. This number will reach 128 nodes by the end of the year 2012.
A location has been found for the new testbed of the EQUIPEX FIT: the basement of building 1 at Rocquencourt. An engineer has been recruited for this project.
Partners: INRIA (Lille, Sophia-Antipolis, Grenoble), INSA, UPMC, Institut Télécom Paris, Institut Télécom Evry, LSIIT Strasbourg.

SWAN

SWAN, Source-aWAre Network coding, is a DIMLSC (domain of main interest: complex software and systems) DIGITEO project. It deals with network coding for multimedia.
Partners: CNRS, Supélec, Université Paris-Sud (L2S), LTCI, LRI, INRIA Hipercom and IEF.

ACRON

ACRON is a DIMLSC (domain of main interest: complex software and systems) DIGITEO project. It deals with analysis and design of self-organized wireless networks. The HIPERCOM team project will study the theoretical limits of wireless networking.
Partners: Supélec (Télécommunications), INRIA, ENS TREC, INRIA HIPERCOM, Université Paris-Sud, IEF.

European projects

OPNEX

The European OPNEX project, Optimization driven Multi-Hop Network Design and Experimentation (See http://www.opnex.eu/) delivers a first principles approach to the design of architectures and protocols for multi-hop wireless networks. Systems and optimization theory is used as the foundation for algorithms that provably achieve full transport capacity of wireless systems. Subsequently a plan for converting the algorithms termed in abstract network models to protocols and architectures

in practical wireless systems is given. Finally a validation methodology through experimental protocol evaluation in real network testbeds is proposed. OPNEX will use recent advances in system theoretic network control, including the backpressure principle, max-weight scheduling, utility optimization congestion control and primal-dual method for extracting network algorithms. These approaches exhibited already vast potential for achieving maximum capacity and full exploitation of resources in abstract network models and found their way to reality in high performance switching architectures and recent variants of TCP that embody the primal-dual optimization principle. Wireless, the fastest growing component of internet today, is also the least understood for the designer due to mobility, rapidly changing topology, radio link unpredictability and volatile load distribution among others. Current approaches used in practice for multi-hop wireless, the basic communication infrastructure for sensor network extensions of the internet, are mostly empirical and heuristic. Our system optimization approach will provide a rigorous integrated system design framework from physical up to network and transport layer that renders itself to validation and comparison with the theoretically optimal performance in terms of throughput, spectrum and energy utilization. The adopted approach on decentralization, communication and computational complexity reduction as well as autonomous operation will lead to implementable algorithms and architectures to be validated eventually in the proposed testbeds.
Partners: CRTH (Greece), Technicolor, Freie Universitaet Berlin (FUB), Politechnika Poznanska (PUT), Inria.

EXPESHARE

The EXPESHARE project, EXPErience SHAring in mobile peer communities, is an ITEA2 project. The aim is to allow virtual communities to exchange multimedia contents and experiences in a legal and secured way, using different types of personal assistants.
Partners: Gemalto, INRIA, INT Evry, City Passenger, NXP Semiconductors,Evry university, Transatel, Brieftec, Capricode, CBT, Comverse, Engineering SpA, Innovalia, Kutalab, Nextel, Nokia, Philips, Shunra Software, SoftwareQuality Systems, Telefonica, University of Oulu, Paderborn university, Politechnica de valencia University, La Spenzia Roma university.

ETARE

ETARE is a project of EDA (European Defense Agency). The goal of the ETARE project is to ease the requirement to transmit more and more information and to interconnect the users in ad hoc networks. These ad hoc networks will link together the different elements on the battlefield (vehicles, foot soldiers, helicopters) and possibly connect them with naval forces. This will be possible through High Data Rate Networking waveforms, which will also insure interoperability between forces. In this project, INRIA's contribution is focused on network layer. INRIA studies the various protocol's ability to handle heterogeneous ad hoc networks as well as QoS features: Legacy routing protocols and geographic aware protocols, Overhead of routing protocols, General QoS architecture and application of this architecture for CSMA and TDMA protocols.
Partners: Thales Italy, Thales France and Belgium, Patria Aviation, Oulu university, Selex, Insta, Sapienza university and Elektrobit.

Associated teams and other international projects

Associated team with Macquarie University, Australia

Our associated team with Prof. Bernard Mans of Macquarie University studies Routing in Intermittently Connected Wireless Networks, (see http://hipercom.inria.fr/RSFCI/home.
In such networks, information remains blocked in a connected component as long as the node motion allows to jump into or form a new connected component. This kind of networks are often alternatively refered as Delay/Disruption Tolerant Networks (DTN) and is the focus of many research efforts worldwide (DARPA, IETF). Our main objective is to specify efficients routing algorithms in delivery time, energy and overhead that allow to forward piece of information or packets toward a distant destination in a remote connected component currently out of reach. Our common studies range from theory to proactice: we focus as well on fundamental issues such as the information propagation speed determination to the specification of a routing algorithm and protocol that approaches this theoretical performances.

Industrial contracts

MANETs

This contract is funded by CELAR (Centre d'Electronique de l'Armement, French MoD/DGA). It focuses on mobile ad hoc networks. CELAR is interested in the standardization done at the IETF and more particularly within the MANET and AUTOCONF groups, where the HIPERCOM team-project is active. Furthermore, this contract addresses topics that belong to DARPA's recent initiatives about new military wireless networks able to adapt to changing conditions. These networks will be self-forming, self-healing, self-configuring and self-optimizing. They will provide an intelligent relaying and an intelligent power management. All these topics are present in the CELAR contract with OLSRv2, multicast protocols, autoconfiguration in IPv6, merge of networks, hierarchical routing.

OCARI2

At the end of the OCARI (Optimization of Ad hoc Communications in Industrial networks) project, funded by ANR, started in February 2007 and ended in 2010, EDF the coordinator decided to continue the project with a restricted number of partners: TELIT, LIMOS (Clermont Ferrand university) and INRIA. The goal was to prove the feasibility on commercially available cards of the OCARI stack designed during the ANR project and to make a public demonstration of this product. During the year 2011, the OCARI stack has been improved and implemented on the ZE51 module of TELIT based on the Texas Instrument CC2530 Chipset.
Partners: EDF, TELIT, LIMOS (Clermont Ferrand university) and INRIA.

Other funding,

Cooperation with ENSI, Tunisia

By means of three successive STIC contracts, we led a fruitful collaboration with Prof. Leila Saidane of ENSI, Tunisia. We published common papers (2 international journals and 8 international conferences). Four research masters have been obtained in Tunisie, three are in preparation. Three PhD Theses have been defended (two in Tunisia and one in France). The last STIC contract is entitled "Auto-adaptativity of a wireless sensor network with mobile agents: toward a green sensor network". It aims to design algorithms and protocols for wireless sensors and mobile agents able to meet application requirements and provide the best performances in the considered environment. To achieve that, a cross-layering approach is considered. The network layer may use the information generated by any other higher or lower layer in the purpose of a better adaptivity to the application or the environment considered. Furthermore, since wireless sensor networks deployment is growing more and more, it is judicious to reduce their ecological impact starting with their design. This project focuses on strategies to improve energy efficiency.

5 New project-team proposal

WAND for Wireless Autonomous/Adhoc Networking and Disruption-tolerance will be the new team after the end of HIPERCOM. WAND will mainly remain focused on the same topics as HIPERCOM but with a few evolutions that are driven by the important changes that have appeared in our domain. First, technology has widely progressed offering much larger computation power and miniaturization. Secondly, applications have greatly evolved: (1) a first trend is collaborative exchange (peer-to-peer, social networks); (2) a second evolution is the birth of brand new applications such as transmissions between vehicles to improve road safety, surveillance networks, global and participatory sensing applications, etc. Thirdly, the proliferation of smart portable devices (such as new-generation phones, PDAs or tablet PCs equipped with multiple advanced capabilities (e.g., cameras, voice to text, text to voice, GPS, play and/or record video, sensors, wireless communication) are changing the way people are communicating, generating, and exchanging data. Lastly, the development of information theory has pushed the research community to test new network algorithms sometimes far from those of existing protocols.

Thus, WAND will tackle challenges related to providing efficient communication in ad hoc networks and more generally, to all networks that are not already organized when set up and consequently, need to spontaneously find a fit between their functioning and the environment. As HiPERCOM, WAND will continue to be primarily focused on the network layer. The evolution of the technology and of the application will reinforce the cross layer approach required to solve the new requirements. Therefore the new team will naturally tackle issues at the medium access (MAC) layer and may be sometimes lead to operate at the physical layer. Of course the requirements of the novel applications will lead the team to be involved in the application layer.

Our four objectives for the next years will be the following ones:

- Models for autonomous wireless networks including the study of mobility patterns, dynamic social graphs and network coding.
- Wireless sensor networks and disruption-tolerant networks: energy efficiency, routing, data gathering and (re)deployment.
- VANETs and military tactical networks.
- New services and protocols for autonomous wireless networks including autoconfiguration.

6 Bibliography of the project-team

In this section, we do not mention the numerous deliverables we wrote for the different contracts we were involved in.

Books and Monographs

[1] Emmanuel Baccelli and Thomas Heide Clausen. Réseaux. In *Introduction à la Science Informatique*, pages 237 – 280. CRDP, May 2011.

[2] Juan Antonio Cordero Fuertes, Emmanuel Baccelli, Philippe Jacquet, and Thomas Heide Clausen. Wired/Wireless Compound Networking. In *Mobile Ad-Hoc Networks: Applications*, pages 349 – 375. InTech, January 2011.

[3] Anis Laouiti, Paul Muhlethaler, and Yasser Toor. Broadcast techniques for vehicular ad hoc networks. In *Wireless technologies in intelligent transportation systems*, Transportation Issues, Policies and R&D Series, pages 205–222. Nova Science, 2011.

Doctoral dissertations and Habilitation theses

[4] Lila Boukhatem. *Mobilité et gestion de ressources.* PhD thesis, université Paris-Sud XI, December 2009.

[5] Aline Carneiro Viana. Putting data delivery into context: Design and evaluation of adaptive networking support for successful communication in wireless self-organizing networks, HDR Thesis, December 2011.

[6] Song Yean Cho. *Efficient Information Dissemination in Wireless Multi-hop Networks.* PhD thesis, Ecole Polytechnique, September 2008.

[7] Juan Antonio Cordero. *Link-State Routing Optimization for Compound Autonomous Systems in the Internet.* PhD thesis, Ecole Polytechnique X, September 2011.

[8] Despina Triantafyllidou. *Exploit Link-State Routing to Improve TCP in Mobile Ad Hoc Networks.* PhD thesis, University of Paris-Sud XI, September 2009.

[9] Ulrich Herberg. *Performance, Scalability, Automatic Management and Internet Integration of Ad Hoc Networks.* PhD thesis, Ecole Polytechnique X, May 2011.

[10] Saoucene Mahfoudh. *Efficacité énergétique dans les réseaux ad hoc et de capteurs : routage, ordonnancement de l'activité des noeuds et cross-layering.* PhD thesis, University of Paris 6, January 2010.

[11] Nestor Mariyasagayam. *Communication Véhiculaires par géolocalisation pour Systèmes de Transports Intelligents.* PhD thesis, Ecole Polytechnique X, June 2011.

[12] Yasser Toor. *Design and optimization of broadcast and MAC protocols for VANETs.* PhD thesis, University of Paris 6, November 2009.

Articles in referred journals and book chapters

[13] P. Muhlethaler A. Laouiti and Y. Toor. Vehicle ad hoc networks (vanets): Applications and related technical issues. *IEEE Communications Surveys and Tutorials*, 2008.

[14] C. Adjih, P. Minet, P. Muhlethaler, E. Baccelli, and T. Plesse. QoS support, security and OSPF interconnection in a MANET using OLSR. *JTIT, Journal of Telecommunications and Information Technology*, September 2008.

[15] Khaldoun Al Agha. Les réseaux de capteurs. *Techniques de l'Ingénieur*, 2010. to appear.

[16] Khaldoun Al Agha, Marc-Henri Bertin, Tuan Dang, Alexandre Guitton, Pascale Minet, Thierry Val, and Jean-Baptiste Viollet. Which wireless technology for industrial wireless sensors network? the development of ocari technology. *IEEE Transactions on Industrial Electronics*, 56(10):13, 2009-10-01.

[17] Khaldoun Al Agha, Gérard Chalhoub, Alexandre Guitton, Erwan Livolant, Saoucene Mahfoudh, Pascale Minet, Michel Misson, Joseph Rahmé, Thierry Val, and Adrien Van Den Bossche. Cross-layering in an industrial wireless sensor network: case study of ocari. *Journal of NetWorks*, 4(6):411..420, 2009-08-15.

[18] M. Abdul Awal and L. Boukhatem. *Radio Resource Management in WiMAX, WiMAX and end-to-end QoS support?* Wiley Editions, 2009. pp. 103-138.

[19] Emmanuel Baccelli, Juan Antonio Cordero, and Philippe Jacquet. Ospf over multi-hop ad hoc wireless communications. *International Journal of Computer Networks & Communications*, September 2010.

[20] Emmanuel Baccelli, Philippe Jacquet, Bernard Mans, and Georgios Rodolakis. Highway Vehicular Delay Tolerant Networks: Information Propagation Speed Properties. *IEEE Transactions on Information Theory*, pages 1 – 12, November 2011.

[21] Francois Baccelli, Bartek Blaszczyszyn, and Paul Mühlethaler. Stochastic analysis of spatial and opportunistic aloha. *IEEE Journal on Selected Areas in Communications*, 27(7):1105 – 1119, 2009-09.

[22] François Baccelli, Bartlomiej Blaszczyszyn, and Paul Mühlethaler. Time-space opportunistic routing with an optimized relay self selection technique in wireless ad hoc networks. *Computer Journal*, 2009-09.

[23] L. Boukhalfa, P. Minet, and S. Midonnet. QoS support in a MANET based on OLSR and CBQ. *International Journal on Advances in Networks and Services*, 2008.

[24] L. Boukhatem and L. Friedman. Multi-sink Relocation with constrained movement in Wireless Sensor Networks . *International Journal of Ad hoc and Sensor Wireless Networks*, 2009. To appear.

[25] L. Chen and J. Leneutre. A game theoretical framework of intrusion detection in heterogenous networks. *IEEE Transactions on Information Forensics and Security (TIFS)*, 2009.

[26] L. Chen and J. Leneutre. On multipath routing in multihop wireless networks: Security, performance and their tradeoff. *EURASIP Journal on Wireless Communications and Networking (JWCN)*, 2009.

[27] G. Dowek, T. Viéville, J.P. Archambault, Emmanuel Baccelli, and B. Wack. Les ingrédients des algorithmes. *Interstices)i(Journal (Online)*, April 2010.

[28] G. Dowek, T. Viéville, J.P. Archambault, Emmanuel Baccelli, and B. Wack. Tout a un reflet numérique. *Interstices)i(Journal (Online)*, January 2010.

[29] Mukul Goyal, Mohd Soperi, Emmanuel Baccelli, Gagan Choudhury, Aman Shaikh, Hossein Hosseini, and Kishor Trivedi. Improving Convergence Speed and Scalability in OSPF: A Survey. *IEEE Communications Surveys & Tutorials*, (99):1 – 21, March 2011.

[30] I. Ben Hamida and L. Boukhatem. An adaptive resource reservation for vehicular mobile networks. *ACM International Journal of Network Management, Wiley*, 19:375 – 398, 2009.

[31] Ulrich Herberg and Thomas Clausen. Security issues in the optimized link state routing protocol version 2 (olsrv2). *International Journal of Network Security & Its Applications (IJNSA)*, April 2010.

[32] P. Jacquet, A. Laouiti, A. Merahi, and G. Rodolakis. Multicast overlay spanning trees in ad hoc networks: Capacity bounds, protocol design and performance evaluation. *Computer Communications*, 31:1400–1412, 2008.

[33] Philippe Jacquet, Bernard Mans, Paul Mühlethaler, and Georgios Rodolakis. Opportunistic routing in wireles ad hoc networks : Upper bounds for the packet propagation speed. *IEEE Journal on Selected Areas in Communications*, 27(7):1192 – 1202, 2009-09.

[34] Philippe Jacquet, Bernard Mans, and Giorgios Rodolakis. Information propagation speed in mobile and delay tolerant networks. *IEEE Transactions on IT*, page 5001..5015, 10 2010.

[35] Nour Kadi and Khaldoun Al Agha. Network Coding Based Flooding in Ad-hoc Wireless Networks Under Mobility Conditions. *Annals of Telecommunication, Springer*, 65(9-10), september-october 2010.

[36] A. Laouti, P. Mühlethaler, and Y. Toor. *Broadcast techniques for VANETs*. Nova Science Publishers, Inc. USA, 2009-09.

[37] Fabrice Le Fessant, Anthonis Papadimitriou, Aline Carneiro Viana, Cigdem Sengul, and Esther Palomar. A Sinkhole Resilient Protocol for Wireless Sensor Networks: Performance and Security Analysis. *Computer Communications*, April 2012.

[38] S. Mahfoudh and P. Minet. EOLSR: an energy efficient routing protocol in wireless ad hoc and sensor networks. *Journal of Interconnection Networks, JOIN, AINA 2008 Conference Special Issue in Routing, Scheduling & Load balancing in Networking Systems*, 2008.

[39] S. Mahfoudh and P. Minet. Maximization of energy efficiency in wireless ad hoc and sensor networks with SERENA. *Journal on Mobile Information Systems*, 5, Number 1, 2009. published by IOS Press.

[40] Saoucene Mahfoudh, Gérard Chalhoub, Pascale Minet, Michel Misson, and Ichrak Amdouni. Node coloring and color conflict detection in wireless sensor networks. *Future Internet*, page 469..504, 10 2010.

[41] Saoucene Mahfoudh, Pascale Minet, and Ichrak Amdouni. Energy efficient routing and node activity scheduling in the ocari wireless sensor network. *Future Internet*, page 308..340, 8 2010.

[42] P. Minet. *End-to-end quality of service engineering in next generation heterogeneous networks*, chapter Different approaches to guarantee quality of service (QoS). coordinated by A. Mellouk, 2008.

[43] P. Minet. *Ad Hoc and Sensor Wireless Networks: Architectures, Algorithms and Protocols*, chapter Energy efficient routing. 2009. edited by Hai Liu, Xiaowen Chu, and Yiu-Wing Leung, published by Bentham.

[44] P. Minet. Guest editor for the special issue on the real-time and network systems (RTNS 2008) conference. *Real-Time Systems Journal*, 43, Issue 2, 2009. published by Springer.

[45] P. Minet and A. Laouiti. *Guide to wireless ad hoc networks*, chapter Multicasting in mobile ad hoc networks. 2009. coordinated by S. Misra, published by Springer.

[46] Dang Nguyen, Pascale Minet, and Thomas Kunz. On the Selection of Cluster Heads in MANETs. *International Journal of Computer Science Issues, IJCSI*, 8, January 2011.

[47] D.Q. Nguyen and P. Minet. MANETs with an interference-aware QoS support based on OLSR. *IJCIS Journal*, 7, Issue 1-4, 2008.

[48] Cigdem Sengul, Aline Carneiro Viana, and Artur Ziviani. A Survey of Adaptive Services to Cope with Dynamics in Wireless Self-Organizing Networks. *ACM Computing Surveys*, December 2011.

[49] André-Luc Beylot T. Ali-Yahiya and Guy Pujolle. Downlink Resource Allocation Strategies for OFDMA Based Mobile WiMAX . *Telecommunication Systems*, 2009.

[50] Ana Christina K. Vendramin, Anelise Munaretto, Myriam Regattieri Delgado, and Aline Carneiro Viana. GrAnt: Inferring Best Forwarders from Complex Networks' Dynamics through a Greedy Ant Colony Optimization. *Computer Networks*, December 2011.

[51] Paulo R. Walenga Junior, Mauro Fonseca, Anelise Munaretto, Aline Carneiro Viana, and Artur Ziviani. ZAP: A Distributed Channel Assignment Algorithm for Cognitive Radio Networks. *Special Issue on Multiple Access Communications in Future-Generation Wireless Networks. Eurasip Journal on Wireless Communications and Networking. Hindawi*, July 2011.

Publications in Conferences and Workshops

[52] Cédric Adjih, Emmanuel Baccelli, Philippe Jacquet, Pascale Minet, Matthias Philipp, and Georg Wittenburg. Deployment Experience with Low Power Lossy Wireless Sensor Networks. In *IAB Workshop on Interconnecting Smart Objects with the Internet*, pages 1 – 3, Prague, Czech Republic, March 2011.

[53] Cédric Adjih, Amina Meraihi Naimi, Pascale Minet, and Thierry Plesse. Ipv6 autoconfiguration for mobile ad-hoc networks: Autolsr. In *Information Systems Technology Panel Symposium, IST-092 / RSY -022, "Military Communications and Networks"*, Wroclaw, Poland, September 2010.

[54] T. Ali-Yahiya and Hakima Chaocuhi. A Quality of Service Based Mobility Management in Heterogenous Wireless Networks. In *International Conference on Next Generation Wired/Wireless Networking*, Saint Petersburg, Russia, September 2009.

[55] Tara Ali-Yahiya and Hakima Chaouchi. Zone Switching Diversity for Hierarchical Resource Allocation in Mobile WiMAX Networks. In *IEEE Mobile WiMAX Symposium*, Napa Valley, USA, July 2009.

[56] I. Amadou and P. Minet. Optimized broadcast in a geographical area of wireless ad hoc and sensor networks. In *AINA 2009*, Bradford, United Kingdom, May 2009.

[57] Ichrak Amdouni, Pascale Minet, and Cédric Adjih. Node coloring in wireless networks: complexity results and grid coloring. In *WMNC 2011, 4th Joint IFIP Wireless and Mobile Networking Conference*, Toulouse, France, October 2011.

[58] M. Abdul Awal and L. Boukhatem. Analysis of feedback prediction error on the downlink performance of OFDMA systems. In *IEEE PIMRC'09: The 20th Personal, Indoor and Mobile Radio Communications Symposium*, Tokyo, Japan, September 2009.

[59] M. Abdul Awal and L. Boukhatem. Effect of feedback prediction on OFDMA system throughput. In *ACM IWCMC'09: International Wireless Communications and Mobile Computing Conference*, Leipzig, Germany, June 2009.

[60] Skander Azzaz, Leila Azzouz Saidane, and Pascale Minet. Repairing Sensors Strategies in Fault-Tolerant Wireless Sensor Networks. In *PE-WASUN 2011, ACM International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks*, Miami, Florida, October 2011.

[61] Emmanuel Baccelli, Thomas Clausen, Ulrich Herberg, and Charles Perkins. Ip links in multihop ad hoc wireless networks? In *Proceedings of the IEEE International Conference on Software Telecommunications and Computer Networks (SOFTCOM), Split, Croatia*, September 2009.

[62] Emmanuel Baccelli, Thomas Clausen, Ulrich Herberg, and Charles Perkins. Multipoint relaying techniques with ospf on ad hoc networks. In *Proceedings of the IEEE International Conference on Systems and Networks Communications (ICSNC), Porto, Protugal*, September 2009.

[63] Emmanuel Baccelli, Thomas Clausen, and Philippe Jacquet. Database exchanges for ad-hoc networks using proactive link state protocols. In *Performance Modelling and Analysis of Heterogeneous Networks, River Publishers, Denmark, Chapter 5, pp. 93–111*, February 2009.

[64] Emmanuel Baccelli, Thomas Clausen, and Philippe Jacquet. The internet engineering task force and the future of the internet. In *European Research Consortium for Informatics and Mathematics, ERCIM News issue n77, p. 20-21*, April 2009.

[65] Emmanuel Baccelli, Thomas Clausen, Philippe Jacquet, and Dang Nguyen. Rfc 5449 ospf multipoint relay (mpr) extension for ad hoc networks. In *Internet Engineering Task Force (IETF) Publications*, February 2009.

[66] Emmanuel Baccelli, Thomas Clausen, and Ryuji Wakikawa. Ipv6 operation for wave - wireless access in vehicular environments. In *Proceedings of IEEE VNC 2010*, Jersey City, USA, December 2010.

[67] Emmanuel Baccelli, Juan Antonio Cordero, and Philippe Jacquet. Optimization of critical data synchronization via link overlay rng in mobile ad hoc networks. In *Proceedings of IEEE MASS 2010*, San Francisco, USA, November 2010.

[68] Emmanuel Baccelli, Juan Antonio Cordero, and Philippe Jacquet. Using relative neighborhood graphs for reliable database synchronization in manets. In *Proceedings of the Fifth IEEE Workshop on Wireless Mesh Networks (WiMesh 2010)*, June 2010.

[69] Emmanuel Baccelli, Philippe Jacquet, Bernard Mans, and Georgios Rodolakis. Information Propagation Speed in Bidirectional Vehicular Delay Tolerant Networks. In *30th IEEE International Conference on Computer Communications (INFOCOM)*, pages 436 – 440, Shanghai, China, June 2011.

[70] Emmanuel Baccelli, Matthias Philipp, and Mukul Goyal. The P2P-RPL Routing Protocol for IPv6 Sensor Networks: Testbed Experiments. In *19th International Conference on Software, Telecommunications and Computer Networks*, pages 1 – 6, Split, Croatia, November 2011.

[71] Emmanuel Baccelli and Mark Townsley. Ip addressing model in ad hoc networks. In *Internet Engineering Task Force (IETF) Working Group Document draft-ietf-autoconf-adhoc-addr-model-00*, October 2009.

[72] F. Baccelli, B. Blaszczyszyn, E. Ermel, and P. Muhlethaler. An optimized relay self selection technique for opportunistic routing in mobile ad hoc networks. In *Proceedings of European Wireless 2008*, pages 1–7, 2008.

[73] F. Baccelli, B. Blaszczyszyn, and P. Muhlethaler. On the performance of time-space opportunistic routing in multihop mobile ad hoc networks. In *Proceedings of WiOpt 2008*, pages 307–316, 2008.

[74] Iskander Banaouas and Paul Mühlethaler. Modeling and improving csma unfairness in mobile ad hoc networks. In *IFIP Annual Mediterranean Ad Hoc Networking IEEE workshop*, Juan-Les-Pins, France, June 2010.

[75] Iskander Banaouas and Paul Mühlethaler. Sensor collaboration in event detection. In *Workshop on Interconnections of Wireless Sensor Networks (IWSN'10)*, Sanata Barbara, California, June 2010.

[76] S. Banaouas and P. Mühlethaler. Performance evaluation of tdma versus csma-based protocols in sinr models. In *European Wireless 2009*, Aalborg, Denmark, May 2009.

[77] M. Barbera, Julinda Stefa, Aline Carneiro Viana, Marcelo Dias De Amorim, and Mathias Boc. VIP Delegation: Enabling VIPs to Offload Data in Wireless Social Mobile Networks. In *The 7th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS)*, Barcelona, Spain, February 2011.

[78] Youghourta Benfattoum, Steven Martin, Ignacy Gawedzki, and Khaldoun Al Agha. Manet routing considering intra-flow interference. In *APARM'10: Asia-Pacific International Symposium on Advanced Reliability and Maintenance Modeling*, Wellington, New Zealand, December 2010.

[79] M-H. Bertin, A. van den Bossche, G. Chalhoub, T. Dang, S. Mahfoudh, J. Rahme, and J-B. Viollet. OCARI for industrial wireless sensor networks. In *invited paper to IFIP Wireless Days Conference*, Dubai, United Arab Emirates, November 2008.

[80] Greg Bigwood, Aline Carneiro Viana, Mathias Boc, and Marcelo Dias De Amorim. Collaborative Data Collection in Global Sensing Systems. In *36th IEEE Conference on Local Computer Networks (LCN) - 4-pages*, Bonn, Germany, October 2011.

[81] B. Blaszczyszyn, A. Laouiti, P. Muhlethaler, and Y. Toor. Conventional routing vs an advanced opportunistic routing scheme using active signaling. In *8th International Conference on ITS Telecommunications*, 2008.

[82] B. Blaszczyszyn, A. Laouiti, P. Muhlethaler, and Y. Toor. Opportunistic broadcast in vanets (ob-van) using active signaling for relays selection. In *8th International Conference on ITS Telecommunications*, 2008.

[83] B. Blaszczyszyn, P. Mühlethaler, and Y. Toor. Maximizing throughput of linear vehicular ad hoc networks (VANETs). In *European Wireless 2009*, Aalborg, Denmark, May 2009.

[84] Bartek Blaszczyszyn and Paul Mühlethaler. Stochastic analysis of non-slotted aloha in wireless ad-hoc networks. In *Infocom*, pages 1 – 9, Etats-Unis San Diego, 2010. IEEE, Xplore. accepted for IEEE Infocom 2010.

[85] Bartek Blaszczyszyn, Paul Mühlethaler, and Iskander Banaouas. Coexistence of radio networks using aloha. In *IFIP Wireless Days Conference*, Italie Venice, 2010.

[86] N. Brahmi, Lila Boukhatem, Nadia Boukhatem, M. Boussedjra, N. Dau Nuy, and Houda Labiod. End-to-End Routing Through a Hybrid Ad Hoc Architecture for V2V and V2I communications. In *IFIP/IEEE Med-Hoc-Net'10*, Juan-Les-Pins, France, June 2010.

[87] L. Chen, S. Iellamo, M. Coupechoux, and P. Godlewski. An auction framework for spectrum allocation with interference constraint in cognitive radio networks. In *29th IEEE Conference on Computer Communications (Infocom 2010)*, San Diego, USA, March 2009.

[88] L. Chen and J. Leneutre. Efficient medium access control design: a game theoretical approach. In *34th IEEE Conference on Local Computer Networks (LCN)*, Zurich, Switzerland, October 2009.

[89] Lin Chen. A Distributed Access Point Selection Algorithm Based on No-Regret Learning for Wireless Access Networks. In *IEEE VTC Spring: IEEE 71st Vehicular Technology Conference*, Taipei, Taiwan, May 2010.

[90] Lin Chen, Stefano Iellamo, Marceau Coupechoux, and Philippe Godlewski. An Auction Framework for Spectrum Allocation with Interference Constraint in Cognitive Radio Networks . In *IEEE INFOCOM: 29th IEEE Conference on Computer Communications*, San Diego, CA, USA, March 2010.

[91] S-Y. Cho and C. Adjih. Dynamic rate selection for wireless broadcast with network coding. In *EKC*, Heidelberg, Germany, August 2008.

[92] S-Y. Cho and C. Adjih. Wireless broadcast with network coding: Dynamic rate selection. In *Med Hoc Net*, Palma de Mallorca, Spain, June 2008.

[93] T. Clausen and U. Herberg. Some considerations on routing in particular and lossy environments. In *The first Interconnecting Smart Objects with the Internet Workshop*. Proceedings, March 2011.

[94] T. Clausen, U. Herberg, and M. Philipp. A critical evaluation of the "ipv6 routing protocol for low power and lossy networks" (rpl) -. In *The 5th IEEE International Conference on Wireless & Mobile Computing, Networking & Communication (WiMob)*. Proceedings, October 2011.

[95] Thomas Clausen and Ulrich Herberg. Multipoint-to-point and broadcast in rpl. In *Proceedings of the First International Symposium on Frontiers in Ubiquitous Computing, Networking and Applications (NeoFUSION 2010)*, September 2010.

[96] Thomas Clausen and Ulrich Herberg. Router and link admittance control in the optimized link state routing protocol version 2 (olsrv2). In *Proceedings of the 4th International Conference on Network and System Security (NSS 2010)*, September 2010.

[97] Thomas Clausen and Ulrich Herberg. Vulnerability analysis of the optimized link state routing protocol version 2 (olsrv2). In *Proceedings of the IEEE International Conference on Wireless Communications, Networking and Information Security (WCNIS2010)*, June 2010.

[98] Juan Antonio Cordero Fuertes, Thomas Heide Clausen, and Emmanuel Baccelli. MPR+SP: Towards a Unified MPR-based MANET Extension for OSPF. In *44th Hawaii International Conference on System Sciences*, pages 1 – 10, Hawaii, United States, February 2011.

[99] Despina Triantafyllidou, and Khaldoun Al Agha. Path-Delay Routing with Path Reservation Improves TCP in Ad Hoc Networks. In *ACM IWCMC'09: International Wireless Communications and Mobile Computing Conference*, Leipzig, Germany, June 2009.

[100] Despina Triantafyllidou, Vasilios Siris, Khaldoun Al Agha. Adaptive setting of TCP's maximum window in ad hoc networks. In *IEEE WCNC'09: Wireless Communications and Networking Conference*, Budapest, Hungary, April 2009.

[101] Marco Di Renzo, Lana Iwaza, Michel Kieffer, Pierre Duhamel, and Khaldoun Al Agha. Robust Wireless Network Coding - An Overview. In *MOBILIGHT'2010: International Conference on Mobile Lightweight Wireless Systems*, Barcelona, Spain, May 2010.

[102] Ilhem Fajjari, Nadjib Aitsaadi, Guy Pujolle, and Hubert Zimmermann. VNR Algorithm: A Greedy Approach For Virtual Networks Reconfigurations. In *Globecom 2011 - IEEE Global Communications Conference, Exhibition and Industry Forum*, page 6, Houston, United States, 2011. IEEE. 6 pages.

[103] L. George and P. Minet. Preserving the consistency of distributed objects with real-time transactions. In *CDUR 2008, Workshop international sur la Cohérence Des Données en Univers Réparti*, Lyon, France, June 2008.

[104] Golnaz Karbaschi, Aline Viana, Steven Martin and Khaldoun Al Agha. On Using Network Coding in Multi Hop Wireless Networks. In *IEEE PIMRC'09: Personal Indoors and Mobile Radio Communications*, Tokyo, Japan, September 2009.

[105] U. Herberg and T. Clausen. Delay tolerant routing with olsrv2 -. In *The 9th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing (EUC)*. Proceedings, October 2011.

[106] Ulrich Herberg. Performance evaluation of using a dynamic shortest path algorithm in olsrv2. In *Proceedings of the 8th Annual Conference on Communication Networks and Services Research (CNSR)*, May 2010.

[107] Ulrich Herberg, Thomas Clausen, and Robert Cole. Manet network management and performance monitoring for nhdp and olsrv2. In *Proceedings of the 6th International Conference on Network and Services Management*, October 2010.

[108] Ulrich Herberg, Thomas Clausen, and Jérome Milan. Digital signatures for admittance control in the optimized link state routing protocol version 2. In *Proceedings of the International Conference on Internet Technology and Applications (iTAP 2010)*, August 2010.

[109] Ulrich Herberg and I. Taylor. Development framework for supporting java ns2 routing protocols. In *Proceedings of the 2010 International Workshop on Future Engineering, Applications and Services (FEAS)*, May 2010.

[110] P. Jacquet, B. Mans, P. Muhlethaler, and G. Rodolakis. Opportunistic routing in wireless ad hoc networks: Upper bounds for the packet propagation speed. In *Mobile Ad Hoc and Sensor Systems, 2008.*, 2008.

[111] P. Jacquet, B. Mans, and G. Rodolakis. Information propagation speed in delay tolerant networks: Analytic upper bounds. In *IEEE International Symposium on Information Theory*, 2008.

[112] P. Jacquet, B. Mans, and G. Rodolakis. Broadcast delay of epidemic routing in intermittently connected networks. In *The 2009 IEEE International Symposium on Information Theory*, Seoul, Korea, July 2009.

[113] Philippe Jacquet and Salman Malik. Local Capacity in Wireless Networks: What Can We Expect Beyond Slotted ALOHA. In *MobiHoc*, May 2011.

[114] Philippe Jacquet and Paul Mühlethaler. Geometric bucket trees: Analysis of linear bucket trees. In *AofA'10*, Vienna, Austria, july 2010.

[115] Philippe Jacquet and Paul Mühlethaler. Mean number of transmissions with csma in a linear network. In *IEEE Vehicular Technology Conference VTC2010-Fall*, Ottawa, Canada, September 2010.

[116] Joseph Rahmé and Khaldoun Al Agha. A State-based Battery Model for Nodes' Lifetime Estimation in Wireless Sensor Networks. In *ACM MobiHoc 2009: International Symposium on Mobile Ad Hoc Networking and Computing*, New Orleans, USA, May 2009. Poster.

[117] Nour Kadi and Khaldoun Al Agha. Distributed Switched Code (DiSC): A Distributed Rateless Code for Broadcast in Ad-hoc Wireless Networks. In *IEEE IWCMC'10: The International Wireless Communications and Mobile Computing Conference*, Caen, France, June 2010.

[118] Nour Kadi and Khaldoun Al Agha. MPR-based Flooding with Distributed Fountain Network Coding. In *IFIP/IEEE Med-Hoc-Net'10*, Juan-Les-Pins, France, June 2010.

[119] Nour Kadi and Khaldoun Al Agha. New degree distribution to improve lt-code in network coding for broadcasting in ad-hoc wireless networks. In *IEEE PIMRC'10: Personal Indoors and Mobile Radio Communications*, Istanbul, Turkey, September 2010.

[120] Niels Karowski, Aline Carneiro Viana, and Adam Wolisz. Optimized Asynchronous Multi-channel Neighbor Discovery. In *IEEE Conference on Computer Communications (Infocom), 5-pages*, Shanghai, China, April 2011.

[121] Khaldoun Al Agha, Nour Kadi and Ivan Stojmenovic. Fountain Codes with XOR of Encoded Packets for Broadcasting and Secure Multi-path Routing in Multi-hop Networks using Network Coding. In *IEEE VTC'04-Spring: Vehicular Technology Conference*, Barcalona, Spain, May 2009. IEEE Explorer.

[122] F. Kribi, P. Minet, and S. Mahfoudh. Redeploying mobile wireless sensor networks with virtual forces. In *IFIP Wireless Days*, Paris, France, December 2009.

[123] A. Laouiti, P. Muhlethaler, F. Sayah, and Y. Toor. Quantitative evaluation of the cost of routing protocol olsr in a vanet. In *Vehicular Technology Conference, 2008. VTC Spring 2008*, pages 2986–2990, 2008.

[124] A. Laouiti, P. Muhlethaler, and Y. Toor. Broadcast techniques for vanets: "wireless technologies for intelligent transportation systems". In *Nova Publications*, 2009.

[125] A. Laouti, P. Mühlethaler, and Y. Toor. Performance of mac protocols in linear vanets under different attenuation and fading conditions. In *IEEE Conference on Intelligent Transportation Systems ITSC 2009*, Saint-Louis, USA, October 2009.

[126] A. Laouti, P. Mühlethaler, and Y. Toor. Reliable opportunistic broadcast for vanets (OB-VAN). In *9th International Conference on ITS Telecommunications*, Lille, France, October 2009.

[127] S. Mahfoudh and P. Minet. An energy efficient routing based on OLSR in wireless ad hoc and sensor networks. In *PAEWN 2008, IEEE IEEE International Workshop on Performance Analysis and Enhancement of Wireless Networks*, Ginowan, Japan, March 2008.

[128] S. Mahfoudh and P. Minet. Performance evaluation of the SERENA algorithm to schedule router nodes activity in wireless ad hoc and sensor networks. In *AINA 2008, IEEE 22nd International Conference on Advanced Information Networking and Applications*, Ginowan, Japan, March 2008.

[129] S. Mahfoudh and P. Minet. Survey of energy efficient strategies in wireless ad hoc and sensor network. In *ICN 2008, IEEE International Conference on Networking*, Cancun, Mexico, April 2008.

[130] S. Mahfoudh and P. Minet. Node activity scheduling in wireless sensor networks. In *RTNS 2009*, Paris, France, October 2009.

[131] Saoucene Mahfoudh and Pascale Minet. Energy-aware routing in wireless ad hoc and sensor networks. In *The International Wireless Communications and Mobile Computing Conference, IWCMC'10*, Caen, France, June 2010.

[132] Salman Malik and Philippe Jacquet. On the Optimal Transmission Scheme to Maximize Local Capacity in Wireless Networks. In *Wireless Days*, Oct. 2011.

[133] Salman Malik and Philippe Jacquet. Optimizing Local Capacity of Wireless Ad Hoc Networks. In *WMNC*, Oct. 2011.

[134] Salman Malik, Philippe Jacquet, and Cédric Adjih. On the Throughput Capacity of Wireless Multi-hop Networks with ALOHA, Node Coloring and CSMA. In *Wireless Days*, Oct. 2011.

[135] Salman Malik, Alonso Silva, and Jean-Marc Kelif. Optimal Base Station Placement: A Stochastic Method Using Interference Gradient In Downlink Case. In *ValueTools*, May 2011.

[136] Béatrice Martin, Cédric Adjih, Paul Mühlethaler, Philippe Jacquet, and Sebastiano Schillaci. Enabling technologies as a migration path of tactical networks to future flexible mobile ad hoc wideband waveform(s). In *Information Systems Technology Panel Symposium, IST-092 / RSY -022, "Military Communications and Networks"*, Wroclaw, Poland, September 2010.

[137] Amina Meraihi Naimi, Cédric Adjih, Pascale Minet, and Thierry Plesse. Experiments with the MOST multicast protocol in a wireless multi-hop network. In *IWCMC 2011, the 7th International Wireless Communications and Mobile Computing Conference*, Istanbul, Turkey, July 2011.

[138] Amina Meraihi Naimi, Cédric Adjih, Pascale Minet, and Georgios Rodolakis. Simulation-based comparison of three wireless multicast routing protocols: Most, molsr and smolsr. In *International Conference on Ad Hoc and Wireless Networks, AdHoc-Now'10*, Edmonton, Canada, August 2010.

[139] P. Minet and S. Mahfoudh. SERENA: Scheduling router nodes activity in wireless ad hoc and sensor networks. In *IWCMC 2008, IEEE International Wireless Communications and Mobile Computing Conference*, Crete Island, Greece, August 2008.

[140] P. Minet and S. Mahfoudh. Cross-layering in wireless sensor networks. In *IWCMC 2009*, Leipzig, Germany, June 2009.

[141] P. Minet and S. Mahfoudh. Energy, bandwidth and time efficiency in data gathering applications. In *IFIP Wireless Days*, Paris, France, December 2009.

[142] Pascale Minet, Saoucene Mahfoudh, Gérard Chalhoub, and Alexandre Guitton. Node coloring in a wireless sensor network with unidirectional links and topology changes. In *IEEE Wireless Communications & Networking Conference - WCNC 2010*, Australie Sydney, 2010.

[143] M. Ould Mohameden, L. Boukhatem, and G. Pujolle. Class Aware Duty Cycle (CADC) to improve QoS of IEEE 802.15.4 Networks. In *IFIP Wireless Days'09*, Paris, France, December 2009.

[144] Paul Mühlethaler, Yasser Toor, and Anis Laouiti. Suitability of hiperlans ey-npma for traffic jam scenarios in vanets itst'2010. In *Intelligent Transport Systems Telecommunications,(ITST),2010 10th International Conference on*, Kyoto, Japan, November 2010.

[145] Dang Nguyen, Pascale Minet, and Thomas Kunz. New Findings on the Complexity of Cluster Head Selection Algorithms. In *WoWMoM 2011, The 12th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks*, Lucca, Italy, June 2011.

[146] D.Q. Nguyen, P. Minet, C. Adjih, and T. Plesse. Implementation and performance evaluation of a quality of service support for OLSR in a real MANET. In *QoSim 2009*, Rome, Italy, March 2009.

[147] Apostolia Papapostolou, Vasilis Friderikos, Tara Ali-Yahiya, and Hakima Chaouchi. Robust and Efficient Routing in Wireless Mesh Networks with Unreliable Nodes. In *International Conference on Next Generation Wired/Wireless Networking*, Saint Petersburg, Russia, September 2009.

[148] Joseph Rahmé, Nicolas Fourty, Khaldoun Al Agha, and Adrien van den Bossche. A recursive battery model for nodes lifetime estimation in wireless sensor networks. In *IEEE WCNC'10: Wireless Communications and Networking Conference*, Sydney, Australia, April 2010.

[149] Mubashir Husain Rehmani, Aline Carneiro Viana, Hicham Khalife, and Serge Fdida. Improving Data Dissemination in Multi-Hop Cognitive Radio Ad-Hoc Networks. In *Third International ICST Conference on Ad Hoc Networks*, Paris, France, September 2011.

[150] Simon Odou, Steven Martin, Khaldoun Al Agha. Admission Control based on Dynamic Rate Constraints in Multi-hop Networks. In *IEEE WCNC'09: Wireless Communications and Networking Conference*, Budapest, Hungary, April 2009.

[151] Simon Odou, Steven Martin, Khaldoun Al Agha. Idle Channel Time Estimation in Multi-hop Wireless Networks. In *IEEE ICC'09: International Conference on Communications*, Dresden, Germany, June 2009.

[152] Ridha Soua and Pascale Minet. A survey on energy efficient techniques in wireless sensor networks. In *WMNC 2011, The 4th Joint IFIP Wireless and Mobile Networking Conference*, Toulouse, France, October 2011.

[153] Ridha Soua and Pascale Minet. A survey on multichannel assignment protocols in wireless sensor networks. In *The 4th Joint IFIP Wireless Days*, Niagara Falls, Ontario, Canada, October 2011.

[154] Ridha Soua, Leila Azouz Saidane, and Pascale Minet. Sensors deployment enhancement by a mobile robot in wireless sensor networks. In *Ninth International Conference on Networks - ICN 2010*, France Les Menuires, 2010.

[155] Ana Christina K. Vendramin, Anelise Munaretto, Myriam Regattieri Delgado, and Aline Carneiro Viana. A Greedy Ant Colony Optimization for Routing in Delay Tolerant Networks. In *IEEE Smart Communication Protocols & Algorithms workshop (SCPA) in conjunction with IEEE Globecom 2011*, Houston, United States, December 2011.

[156] Walter Grote, Gustavo Sarmiento and Khaldoun Al Agha. Performance Analysis of Slotted CSMA/CA IEEE 802.15.4 with Heterogeneous No-Acknowledged Uplink Traffic. In *IEEE/IFIP NTMS'09: International Conference on New Technologies, Mobility and Security*, Cairo, Egypt, December 2009.

[157] W. Xie, Mukul Goyal, Hossein Hosseini, J. Martocci, Y. Bashir, Emmanuel Baccelli, and Arjan Durresi. A performance analysis of point-to-point routing along a directed acyclic graph in low power and lossy networks. In *Proceedings of NBiS 2010*, Takayama, Japan, September 2010.

[158] W. Xie, Mukul Goyal, Hossein Hosseini, J. Martocci, Y. Bashir, Emmanuel Baccelli, and Arjan Durresi. Routing loops in dag-based low power and lossy networks. In *oceedings of the IEEE Advanced Information Networking and Applications (AINA)*, Perth, Australia, April 2010.

Standardization

[159] E. Baccelli, T. Clausen, P. Jacquet, and D. Nguyen. Ospf mpr extension for ad hoc networks. draft-ietf-ospf-manet-mpr-03, 2008.

[160] E. Baccelli and C. Perkins. Multi-hop ad hoc wireless communication - internet-draft (work in progress), November 2011.

[161] Emmanuel Baccelli and Mark Townsley. Ip addressing model in ad hoc networks, September 2010.

[162] Anders Brandt, Emmanuel Baccelli, and Robert Cragie. Applicability statement: The use of rpl in building and home environments draft-00, April 2010.

[163] T. Clausen, A. Camacho, J. Yi, A. Colin de Verdiere, Y. Igarashi, H. Satoh, and Y. Morii. Experience with the loadng routing protocol for llns - internet-draft (work in progress), October 2011.

[164] T. Clausen, A. Colin de Verdiere, J. Yi, A. Niktash, Y. Igarashi, H. Satoh, and U. Herberg. The lln on-demand ad hoc distance-vector routing protocol - next generation (loadng) - internet-draft (work in progress), October 2011.

[165] T. Clausen, C. Dearlove, and J. Dean. Rfc6130: Mobile ad hoc network (manet) neighborhood discovery protocol (nhdp), March 2011.

[166] T. Clausen, C. Dearlove, and P. Jacquet. The optimized link state routing protocol version 2. draft-ietf-manet-olsrv2-07, 2008.

[167] T. Clausen, C. Dearlove, and P. Jacquet. The optimized link state routing protocol version 2 (olsrv2) draft-12 - internet-draft (work in progress), July 2011.

[168] Thomas Clausen, Chris Dearlove, and Justin Dean. Manet neighborhood discovery protocol (nhdp) draft-12, March 2010.

[169] Thomas Clausen, Chris Dearlove, and Justin Dean. Manet neighborhood discovery protocol (nhdp) draft-13, July 2010.

[170] Thomas Clausen, Chris Dearlove, and Philippe Jacquet. Link metrics for olsrv2 draft-05, June 2010.

[171] Thomas Clausen, Chris Dearlove, and Philippe Jacquet. The optimized link state routing protocol version 2 (olsrv2) draft-11, April 2010.

[172] M. Goyal, E. Baccelli, A. Brandt, and J. Martocci. A mechanism to measure the quality of a point-to-point route in a low power and lossy network - internet-draft (work in progress), October 2011.

[173] M. Goyal, E. Baccelli, and J. Martocci. he direction field in routing metric/constraint objects used in rpl - internet-draft (work in progress), February 2011.

[174] M. Goyal, E. Baccelli, M. Philipp, A. Brandt, and J. Martocci. Reactive discovery of point-to-point routes in low power and lossy networks - internet-draft (work in progress), November 2011.

[175] M. Goyal, N. Dejean, D. Barthel, E. Baccelli, and J. Martocci. Dis modifications - internet-draft (work in progress), September 2011.

[176] Mukul Goyal and Emmanuel Baccelli. Reactive discovery of point-to-point routes in low power and lossy networks, October 2010.

[177] U. Herberg and T. Clausen. Cryptographical signatures in nhdp draft-00 - internet-draft (work in progress), July 2011.

[178] U. Herberg and T. Clausen. Cryptographical signatures in nhdp draft-01 - internet-draft (work in progress), March 2011.

[179] U. Herberg and T. Clausen. Cryptographical signatures in nhdp draft-02 - internet-draft (work in progress), July 2011.

[180] U. Herberg and T. Clausen. Manet cryptographical signature tlv definition draft-03 - internet-draft (work in progress), March 2011.

[181] U. Herberg and T. Clausen. Manet cryptographical signature tlv definition draft-04 - internet-draft (work in progress), July 2011.

[182] U. Herberg and T. Clausen. Manet cryptographical signature tlv definition draft-05 - internet-draft (work in progress), July 2011.

[183] U. Herberg and T. Clausen. Manet cryptographical signature tlv definition draft-06 - internet-draft (work in progress), September 2011.

[184] U. Herberg, R. Cole, and T. Clausen. Definition of managed objects for the optimized link state routing protocol version 2 draft-02 - internet-draft (work in progress), January 2011.

[185] Ulrich Herberg and Thomas Clausen. Manet cryptographical signature tlv definition draft-00, June 2010.

[186] Ulrich Herberg and Thomas Clausen. Manet cryptographical signature tlv definition draft-01, July 2010.

[187] Ulrich Herberg and Thomas Clausen. Manet cryptographical signature tlv definition draft-02, November 2010.

[188] Ulrich Herberg and Thomas Clausen. Manet cryptographical signature tlv definition draft-03, March 2010.

[189] Ulrich Herberg and Thomas Clausen. Yet another autoconf proposal (yaap) for mobile ad hoc networks draft-00, July 2010.

[190] Ulrich Herberg, Robert Cole, and Ian Chakeres, November 2010.

[191] Ulrich Herberg, Robert Cole, and Ian Chakeres. Definition of managed objects for the neighborhood discovery protocol draft-03, March 2010.

[192] Ulrich Herberg, Robert Cole, and Ian Chakeres. Definition of managed objects for the neighborhood discovery protocol draft-04, July 2010.

[193] Ulrich Herberg, Robert Cole, and Ian Chakeres. Definition of managed objects for the neighborhood discovery protocol draft-05, November 2010.

[194] Ulrich Herberg, Robert Cole, and Thomas Clausen. Definition of managed objects for the optimized link state routing protocol version 2 draft-02, July 2010.

[195] Y. Lacharite, M. Wang, P. Minet, and T. Clausen. Hierarchical OLSR, 2008.

[196] P. Levis, T. Clausen, J. Hui, O. Gnawli, and J. Ko. Rfc6206: The trickle algorithm, March 2011.

[197] Philip Levis and Thomas Clausen. The trickle algorithm draft-00, February 2010.

[198] Philip Levis and Thomas Clausen. The trickle algorithm draft-01, March 2010.

[199] A. Szwabe, P. Misiorek, M. Urbanski, and E. Baccelli. Olsrv2 backpressure traffic engineering extension - internet-draft (work in progress), May 2011.

[200] A. Szwabe, A. Nowak, E. Baccelli, J. Yi, and B. Perrein. Multi-path for optimized link state routing protocol version 2 - internet-draft (work in progress), May 2011.

Internal Reports

[201] C. Adjih and S. Y. Cho. Wireless broadcast with network coding: A connected dominating sets approach. Technical Report RR-6547, INRIA, June 2008.

[202] C. Adjih and P. Jacquet. Architecture générale (pour olsr avec métriques). Technical Report Contract Luceor-INRIA, INRIA, April 2008.

[203] C. Adjih and P. Jacquet. Olsr avec métriques. Technical Report Contract Luceor-INRIA, INRIA, October 2008.

[204] C. Adjih, A. Meraihi, and P. Minet. Autoconfiguration for OLSR-Ng: AUTOLSR. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, March 2009.

[205] C. Adjih, A. Meraihi, and P. Minet. AUTOLSR Specification: OLSR-Ng with Autoconfiguration. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, September 2009.

[206] C. Adjih, A. Meraihi, and P. Minet. Fusion of MANET/OLSR networks: Analysis. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, September 2009.

[207] Cédric Adjih, Emmanuel Baccelli, Philippe Jacquet, Pascale Minet, Matthias Philipp, and Georg Wittenburg. Deployment Experience with Low Power Lossy Wireless Sensor Networks. Research Report RR-7551, INRIA, February 2011.

[208] Cédric Adjih and Song Yean Cho. Wireless broadcast with network coding: Energy efficiency, optimality and coding gain in lossless wireless networks. Rapport de recherche, 2009. RR-7011.

[209] Ichrak Amdouni, Cédric Adjih, and Pascale Minet. On the Coloring of Grid Wireless Sensor Networks: the Vector-Based Coloring Method. Research Report RR-7756, INRIA, October 2011.

[210] Ichrak Amdouni, Pascale Minet, and Cédric Adjih. Node coloring for dense wireless sensor networks. Research Report RR-7588, INRIA, March 2011.

[211] Ichrak Amdouni, Pascale Minet, and Cédric Adjih. OSERENA, an Optimized Coloring Algorithm for Dense or Large Scale Wireless Networks. Research Report RR-7785, INRIA, November 2011.

[212] Emmanuel Baccelli, Thomas Heide Clausen, and Philippe Jacquet. Ad hoc networking in the internet: A deeper problem than it seems. Technical Report RR-6725, INRIA, 2008.

[213] Emmanuel Baccelli, Juan Antonio Cordero, and Philippe Jacquet. Multi-hop wireless networking with ospf: Mpr-based routing extensions for manets. Technical report, February 2009.

[214] Emmanuel Baccelli, Juan Antonio Cordero Fuertes, and Philippe Jacquet. Multi-hop wireless networking with ospf: Mpr-based routing extensions for manets. Rapport de recherche, 2009. RR-6822.

[215] Emmanuel Baccelli, Philippe Jacquet, Bernard Mans, and Georgios Rodolakis. Information propagation speed in bidirectional vehicular delay tolerant networks. Rapport de recherche RR-7266, INRIA, December 2010.

[216] Emmanuel Baccelli, Philippe Jacquet, Bernard Mans, and Georgios Rodolakis. Information Propagation Speed in Bidirectional Vehicular Delay Tolerant Networks. Research Report RR-7266, INRIA, July 2011.

[217] S. Y. Cho and C. Adjih. Wireless broadcast with network coding in mobile ad-hoc networks: Dragoncast. Technical Report RR-6569, INRIA, July 2008.

[218] Thomas Clausen, Emmanuel Baccelli, and Ryuji Wakikawa. Ipv6 operation for wave - wireless access in vehicular environments. Rapport de recherche RR-7383, INRIA, September 2010.

[219] Thomas Clausen and Ulrich Herberg. Comparative study of rpl-enabled optimized broadcast in wireless sensor networks. Rapport de recherche RR-7296, INRIA, May 2010.

[220] Thomas Clausen and Ulrich Herberg. Multipoint-to-point and broadcast in rpl. Rapport de recherche RR-7244, INRIA, April 2010.

[221] Thomas Clausen and Ulrich Herberg. Router and link admittance control in the optimized link state routing protocol version 2 (olsrv2). Rapport de recherche RR-7248, INRIA, April 2010.

[222] Thomas Clausen and Ulrich Herberg. Security issues in the optimized link state routing protocol version 2 (olsrv2). Rapport de recherche RR-7218, INRIA, March 2010.

[223] Thomas Clausen and Ulrich Herberg. Study of multipoint-to-point and broadcast traffic performance in rpl. Rapport de recherche RR-7384, INRIA, September 2010.

[224] Thomas Clausen and Ulrich Herberg. Vulnerability analysis of the optimized link state routing protocol version 2 (olsrv2). Rapport de recherche RR-7203, INRIA, February 2010.

[225] Thomas Clausen and Ulrich Herberg. Yet another autoconf proposal (yaap) for mobile ad hoc networks. Rapport de recherche RR-7341, INRIA, July 2010.

[226] Thomas Clausen, Ulrich Herberg, and Jérome Milan. Digital signatures for admittance control in the optimized link state routing protocol version 2. Rapport de recherche RR-7216, INRIA, February 2010.

[227] Thomas Heide Clausen. Manet router configuration recommendations. Rapport de recherche, 2009. RR-6852.

[228] Thomas Heide Clausen and Axel Colin De Verdière. The LLN On-demand Ad hoc Distance-vector Routing Protocol - Next Generation (LOADng). Research Report RR-7692, INRIA, July 2011.

[229] Thomas Heide Clausen and Ulrich Herberg. A Comparative Performance Study of the Routing Protocols LOAD and RPL with Bi-Directional Traffic in Low-power and Lossy Networks (LLN). Research Report RR-7637, INRIA, June 2011.

[230] Thomas Heide Clausen and Ulrich Herberg. Delay Tolerant Routing with OLSRv2. Research Report RR-7662, INRIA, June 2011.

[231] Thomas Heide Clausen and Ulrich Herberg. Some Considerations on Routing In Particular and Lossy Environments. Research Report RR-7540, INRIA, February 2011.

[232] Thomas Heide Clausen, Ulrich Herberg, and Matthias Philipp. A Critical Evaluation of the "IPv6 Routing Protocol for Low Power and Lossy Networks" (RPL). Research Report RR-7633, INRIA, May 2011.

[233] Thomas Heide Clausen, Ulrich Herberg, and Jiazi Yi. Vulnerability Analysis of the Simple Multicast Forwarding (SMF) Protocol for Mobile Ad Hoc Networks. Research Report RR-7638, INRIA, June 2011.

[234] Robert Cole and Ulrich Herberg. Performance Analysis of SNMP in OLSRv2-routed MANETs. Research Report RR-7407, INRIA, July 2011.

[235] Juan Antonio Cordero, Emmanuel Baccelli, and Philippe Jacquet. Ospf over multi-hop ad hoc wireless communications. Rapport de recherche RR-7268, INRIA, April 2010.

[236] Juan Antonio Cordero, Thomas Clausen, and Emmanuel Baccelli. Mpr+sp: Towards a unified mpr-based manet extension of ospf. Rapport de recherche RR-7319, INRIA, June 2010.

[237] Juan Antonio Cordero, Philippe Jacquet, and Emmanuel Baccelli. A Theoretical Model for Analyzing the Impact of Jitter-based Techniques on Flooding over Wireless Ad Hoc Networks. Research Report RR-7701, INRIA, July 2011.

[238] Juan Antonio Cordero, Matthias Philipp, and Emmanuel Baccelli. Compound Wired/Wireless Internetworking with OSPF. Research Report RR-7642, INRIA, June 2011.

[239] Despina Triantafyllidou and Khaldoun Al Agha. Improve tcp performance in ad hoc networks, with delay routing and path reservation. Technical Report 1514, LRI: Laboratoire de Recherche en Informatique, http://www.lri.fr, March 2009.

[240] N. Diez, L. Boukhatem, and I. Stojmenovic. Link Transport Time and Infrastructure Aided Delay Efficient Routing in Vanets. Technical Report 1513, LRI, Mars 2009.

[241] Ulrich Herberg. Integrating java support for routing protocols in ns2. Rapport de recherche, 2009. RR-7075.

[242] Ulrich Herberg. Performance analysis of snmp in olsrv2-routed manets. Rapport de recherche RR-7407, INRIA, October 2010.

[243] Ulrich Herberg. Performance evaluation of using a dynamic shortest path algorithm in olsrv2. Rapport de recherche RR-7174, INRIA, January 2010.

[244] Ulrich Herberg, Thomas Clausen, and Robert Cole. Manet network management and performance monitoring for nhdp and olsrv2. Rapport de recherche RR-7311, INRIA, June 2010.

[245] Ulrich Herberg, Nestor Mariyasagayam, and Thomas Clausen. Comparison of nhdp and mhvb for neighbor discovery in multi-hop ad hoc networks. Rapport de recherche RR-7173, INRIA, January 2010.

[246] HIPERCOM. Analysis of three MANET multicast protocols: SMOLSR, MOLSR and MOST. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, August 2008.

[247] HIPERCOM. Simulation of three MANET multicast protocols: SMOLSR, MOLSR and MOST. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, September 2008.

[248] P. Jacquet. Realistic wireless network model with explicit capacity evaluation. Technical Report RR-6407, INRIA, 2008.

[249] P. Jacquet. Space time relaying versus information causality. Technical Report RR-6428, INRIA, 2008.

[250] P. Jacquet, T. Papakonstantinou, and G. Rodolakis. Localization and path tracking using the ieee 802.11 infrastructure. Technical Report RR-6499, INRIA, 2008.

[251] P. Jacquet and L. Viennot. Remote-spanners: What to know beyond neighbors. Technical Report RR-6679, INRIA, 2008.

[252] Philippe Jacquet. Non unitary random walks. Rapport de recherche, 2009.

[253] Philippe Jacquet. Information propagation speed versus transport capacity in mobile ad hoc wireless networks. Research report, INRIA, March 2011.

[254] Philippe Jacquet and Salman Malik. Optimal transmission schemes in wireless networks and their comparison with simple aloha based scheme. Technical Report RR-7339, INRIA, July 2010.

[255] Philippe Jacquet, Yacine Mezali, and Georgios Rodolakis. Indoor positioning using the ieee 802.11 infrastructure. Rapport de recherche RR-7294, INRIA, June 2010.

[256] Philippe Jacquet and Szpankowski Wojciech. New analysis of the asymptotic behavior of the lempel-ziv compression algorithm. Rapport de recherche, INRIA, April 2010.

[257] Joseph Rahmé and Khaldoun Al Agha. A recursivemodel for battery lifetime estimationin wireless sensor networks. Technical Report 1525, LRI: Laboratoire de Recherche en Informatique, http://www.lri.fr, September 2009.

[258] Ana Cristina Kochem Vendramin, Anelise Munaretto, Myriam Regattieri Delgado, and Aline Carneiro Viana. GrAnt: Inferring Best Forwarders from Complex Networks' Dynamics through a Greedy Ant Colony Optimization. Research Report RR-7694, INRIA, July 2011.

[259] Guilherme Maia, Daniel L. Guidoni, Aline Carneiro Viana, André L. L. Aquino, Raquel A. F. Mini, and Antonio A. F. Loureiro. ProFlex: A Probabilistic and Flexible Data Storage Protocol for Heterogeneous Wireless Sensor Networks. Research Report RR-7695, INRIA, July 2011.

[260] A. Meraihi, C. Adjih, and P. Minet. Autoconfiguration for OLSR-Ng: AUTOLSR - Validation and Qualification. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, September 2009.

[261] A. Meraihi, C. Adjih, and P. Minet. Experiments with OLSRng Routing in a MANET. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, March 2009.

[262] P. Minet, C. Adjih, and P. Muhlethaler. Analysis of OLSRNg. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, February 2008.

[263] P. Minet, C. Adjih, and P. Muhlethaler. Building blocks for dynamic routing in HF. Technical Report Contract CELAR-INRIA 06 42 215, INRIA, May 2008.

[264] Nour Kadi and Khaldoun Al Agha. Switched code. Technical Report 1527, LRI: Laboratoire de Recherche en Informatique, http://www.lri.fr, September 2009.

[265] J. Rahmé and L. Boukhatem. Predictive Sink Mobility for Target Tracking in Sensor Networks. Technical Report 1512, LRI, Mars 2009.

[266] Marco Valerio Barbera, Aline Carneiro Viana, Marcelo Dias De Amorin, and Julinda Stefa. VIP Delegation: Enabling VIPs to Offload Data in Wireless Social Mobile Networks. Research Report RR-7563, INRIA, March 2011.

Other Reports

[267] I. Amadou. Diffusion optimisée dans une zone géographique pour un réseau de capteurs ou un réseau mobile ad hoc, June 2008.

[268] F. Kribi. Redéploiement dans un réseau de capteurs mobiles, June 2009. Mémoire de fin d'étude ENSI, Tunis.

[269] Khalil Mougou. Redéploiement dans un réseau de capteurs mobiles en fonction de centres d'intérêt. Technical report, ENSI Tunis Tunisia, June 2010.