INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team hipercom

HIgh PERformance COMmunication

Paris - Rocquencourt

THEME COM

Activity Report

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2. Overall Objectives

2.1. Overall Objectives

Hipercom project-team aims to design, evaluate and optimize the telecommunication algorithms. The aimed areas are protocols, new telecommunication standards and quality of service management in 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 local area networking, local loops, in particular mobile ad hoc networking. However the thematic extends to the information theory and modelization of internet graph and traffics.

The scientific foundations are the following:

- Analytic information theory,
- Methodology for telecommunication algorithm evaluation,
- Traffic and network architectures evaluation,
- Algorithms conception and implementation

The objectives assigned to HIPERCOM were:

- Massive mobile dense wireless networks
- New services and protocols
- Wireless and backbone integration
- Convergence 4G manet internet

The last objective about the convergence between 4G and manet has been put aside to the benefit of the three other objectives. The main reason is because there is no real demand in this very technological item.

3. Scientific Foundations

3.1. Analytical information theory

Keywords: *channel capacity*, *compression*, *predictors*.

Participants: Philippe Jacquet, Wojciech Szpankowski.

Information theory Branch of mathematics dedicated to the quantification of the performance of a medium to carry information. Initiated by Shannon in 1948.

Abstract. Information theory and analytical methods play a central role in the networking technology. It identifies the key parameter that must be quantified in order to characterize the performance of a network.

The analytical information theory is part of the foundations of the Hipercom project. This is a tool box that has been collected and adapted from the areas of the analysis of algorithms and the information theory. It provides powerful tool for the analysis of telecommunication algorithms. The analysis of the behavior of such algorithms in their asymptotic range are fundamental in order to identify their critical parts. It helps to design and properly scale the protocols. Application of analytical information theory ranges from channel capacity computations, compression algorithm performance evaluation, predictor designs.

3.2. Methodology of telecommunication algorithm evaluation

Keywords: *deterministic performance*, *probabilistic performance*.

Participants: Cédric Adjih, Emmanuel Baccelli, Thomas Clausen, Philippe Jacquet, Paul Mühlethaler, Saoucène Mahfoudh, Pascale Minet, Farid Sayah, Yasser Toor.

Abstract. We develop our performance evaluation tools towards deterministic performance and probabilistic performance. Our tools range from mathematical analysis to simulation and real life experiment of telecommunication algorithms.

One cannot design good algorithms without good evaluation models. Hipercom project team has an historically strong experience in performance evaluation of telecommunication systems, notably when they have multiple access media. We consider two main methodologies:

- Deterministic performance analysis,
- Probabilistic performance analysis

In the deterministic analysis, the evaluation consists to identify and quantify the worst case scenario for an algorithm in a given context. For example to evaluate an end-to-end delay. Mathematically it consists into handling a (max,+) algebra. Since such algebra is not commutative, the complexity of the evaluation of an end-to-end delay frequently grows exponentially with the number of constraints. Therefore the main issue in the deterministic evaluation of performance is to find bounds easier to compute in order to have practical results in realistic situations.
In the probabilistic analysis of performance, one evaluate the behavior of an algorithm under a set of parameters that follows a stochastic model. For example traffic may be randomly generated, nodes may move randomly on a map. The pionneer works in this area come from Knuth (1973) who has systemized this branch. In the domain of telecommunication, the domain has started a significant rise with the appearance of the problematic of collision resolution in a multiple access medium. With the rise of wireless communication, new interesting problems have been investigated.
The analysis of algorithm can rely on analytical methology which provides the better insight but is practical in very simplistic models. Simulation tools can be used to refine results in more complicated models. At the end of the line, we proceed with real life experiments. To simplify, experiments check the algorithms with 10 nodes in maximum, simulations with 100 nodes maximum, analytical tools with more 1,000 nodes, so that the full range of applicability of the algorithms is investigated.

3.3. Network traffic and architecture models

Keywords: *dynamic nodes*, *mobility models*, *network topologies*, *traffic source models*.

Participants: Cédric Adjih, Philippe Jacquet, Georges Rodolakis.

Power laws probability distributions that decays has inverse power of the variable for large values of the variable. Power laws are frequent in economic and statistical analysis (see Pareto law). Simple models such as Poisson processes and finite state Markov processes don't generate distributions with power laws.

Abstract. Network models are important. We consider four model problems: topology, mobility, dynamics and traffic models.

One needs good and realistic models of communication scenarios in order to provide pertinent performance evaluation of protocols. The models must assess the following key points:

- The architecture and topology: the way the nodes are structured within the network
- The mobility: the way the nodes move
- The dynamics: the way the nodes change status
- The traffic: the way the nodes commnunicate

For the architecture there are several scales. At the internet scale it is important to identify the patterns which dictate the node arrangement. For example the internet topology involves many power law distribution in node degree, link capacities, round trip delays. These parameters have a strong impact in the performance of the global network. At a smaller scale there is also the question how the nodes are connected in a wireless network. There is a significant difference between indoor and outdoor networks. The two kinds of networks differ on wave propagation. In indoor networks, the obstacles such as walls, furniture, etc, are the main source of signal attenuations. In outdoor networks the main source of signal attenuation is the distance to the emitter. This lead to very different models which vary between the random graph model for indoor networks to the unit graph model for outdoor networks.
The mobility model is very important for wireless network. The way nodes move may impact the performance of the network. For example it determines when the network splits in distinct connected components or when these components merge. With random graph models, the mobility model can be limited to the definition of a link status holding time. With unit disk model the mobility model will be defined according to random speed and direction during random times or random distances. There are some minor complications on the border of the map.

The node dynamic addresses the elements that change inside the node. For example its autonomy, its bandwidth requirement, the status of server, client, etc. Pair to pair networks involve a large class of users who frequently change status. In a mobile ad hoc network, nodes may change status just by entering a coverage area, or because some other nodes leaves the coverage area.
The traffic model is very most important. There are plenty literature about trafic models which arose when Poisson models was shown not to be accurate for real traffics, on web or on local area networks. Natural traffic shows long range dependences that don't exist in Poisson traffic. There are still strong issues about the origin of this long range dependences which are debated, however they have a great impact on network performance since congestions are more frequent. The origin are either from the distribution of file sizes exchanged over the net, or from the protocols used to exchange them. One way to model the various size is to consider on/off sources. Every time a node is on it transfers a file of various size. The TCP protocol has also an impact since it keeps a memory on the network traffic. One way to describe it is to use an on/off model (a source sending packets in transmission windows) and to look at the superposition of these on/off sources.

3.4. Algorithm conception and implementation

Keywords: *Access protocols*, *QoS*, *routing*, *scheduling*.

Participants: Cédric Adjih, Emmanuel Baccelli, Thomas Clausen, Philippe Jacquet, Paul Mühlethaler, Saoucène Mahfoudh, Amina Meraihi, Pascale Minet, Farid Sayah, Yasser Toor.

Abstract. Algorithms are conceived with focal point on performance. The algorithms we specify in detail range between medium access control to admission control and quality of service management.

The conception of algorithms is an important focus of the project team. We specify algorithms in the perspective of achieving the best performance for communication. We also strive to embed those algorithms in protocols that involve the most legacy from existing technologies (Operating systems, internet, Wifi). Our aim with this respect is to allow code implementations for real life experiment or imbedded simulation with existing network simulators. The algorithm specified by the project ranges from multiple access schemes, wireless ad hoc routing, mobile multicast management, Quality of service and admission controls. In any of these cases the design emphasize the notions of performance, robustness and flexibility. For example, a flooding technique in mobile ad hoc network should be performing such to save bandwidth but should not stick too much close to optimal in order to be more reactive to frequent topology changes. Some telecommunication problems have NP hard optimal solution, and an implementable algorithm should be portable on very low power processing unit (e.g. sensors). Compromise are found are quantified with respect to the optimal solution.

4. Application Domains

4.1. Wireless mobile ad hoc networks

Keywords: *Community Networks*, *Services over mobile networks*, *Wireless mobile ad hoc networks*.

Abstract. Mobile wireless networks have numerous applications in rescue and emergency operation, military tactical networking and in wireless high speed access to the internet.

A mobile ad hoc network is a network made of a collection of mobile nodes that gather spontaneously and communicate without requiring a pre-existing infrastructure. Of course a mobile ad hoc network use a wireless communication medium. They can be applied in various contexts:

- military;
- rescue and emergency;
- high speed access to internet.

The military context is the most obvious application of mobile ad hoc networks.

Soldiers invading a country won't susbscribe in advance to the local operator. On the reverse side, home units won't use their local operators firstly because they will likely be disrupted in the first hours of the conflict, and secondly because a wireless communication via an operator is not stealth enough to protect the data and the units. In Checheny, a general has been killed by a missile tracking the uplink signal of his portable phone.
The rescue context is halfway between military and civilian applications. In the september 11 disaster, most of the phone base station of the area have knocked out in less than twenty minutes. The remaining base stations were unable to operate because they could not work in ad hoc mode. The Wireless Emergency Rescue Team recommanded afterward that telecom operators should provide ad hoc mode for their infrastructure in order to operate in emergency situation in plain cooperation with police, firemen and hospital networks.
Mobile ad hoc network provide an enhanced coverage for high speed wireless access to the internet. The now very popular WLAN standard, WiFi, provides much larger capacity than mobile operator networks. Using a mobile ad hoc network around hot spots will offer high speed access to much larger community, including cars, busses, trains and pedestrians.

4.2. Services over mobile networks

Abstract. New wireless network calls for new services that fullfil the requirement in terms of mobility and capacity.

The generalization of a new generation of mobile networks calls for a new set of services and applications. For example:

- Indoor and outdoor positioning
- Service discovery and localisation
- Multicast and quality of services

Quality of service has become the central requirement that users expect from a network. High throughput, service continuity are critical issue for multimedia application over the wireless internet where the bandwidth is more scarce than in the wired world. 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.

4.3. Community Network

Abstract. There is an increasing demand to deploy network within a community, rural or urban, with cabled or wireless access.

Community networks or citizen network are now frequent in big cities. In America most of the main cities have a community network. A community network is using the communication resource of each member (ADSL, Cable and wireless) to provide a general coverage of a city. Pedestrian in the street or in city mails can communicate via a high speed mobile mesh network. This new trend now appears in Europe with many experiments of the OLSR routing protocol in Paris, Lille, Toulouse, Berlin, Bruxelles, Seattle. The management of such networks is completely distributed and makes them very robust to faults. There is room for smart operators in this business.

5. Software

5.1. OLSR softwares

Keywords: *Internet protocol*, *routing protocol*.

Participants: Cédric Adjih [correspondant], Emmanuel Baccelli, Thomas Clausen, Philippe Jacquet, Saoucène Mahfoudh, Amina Meraihi, Pascale Minet, Paul Mühlethaler, Farid Sayah, Yasser Toor.

Abstract. The routing protocol OLSR has been implemented in Linux and Windows for real experiment with Wireless LAN networks. There are also implementations for simulator such as NS-2 and Opnet.

The current version of OLSR, called OOLSR (for Object oriented OLSR), is IETF RFC compliant with multiple interfaces and tunable mobility parameters and has been fully tested during the three successive OLSR Interops in San Diego, August 2004, Paris August 2005 and Tokyo/Niigata 2006 . This version runs with Linux and Windows. The linux daemon is very easy to install and can be downloaded from the web page. There have been more than 6000 downloads of the code which is exceptional for a routing protocol. This version also contains feature adaptable to wireless driver, such as the signal power monitor.
Related to OLSR, we have implemented and succesfully tested in linux the Multicast routing protocol SMOLSR (Simple Multicast on OLSR) that efficiently broadcast data on wireless networks using MultiPoint Relays and the MOLSR (Multicast over OLSR) protocol. We have also implemented the MOST protocol (Multicast Overlay Spanning Trees) that forwards data to multicast group members on an overlay tree built on an OLSR shortest path tree.
Numerous code (including one in Python) have been developped for experiment and simulation (NS-2, Opnet). See http://hipercom.inria.fr/olsr/.
Other modules have been added to OOLSR dealing with autoconfiguration, security and QoS. Some of these modules have been experimented on the CELAR platform consisting of 18 nodes.
The code development of the next version of OLSR (OLSRv2) is under progress both at INRIA ROCQUENCOURT and at POLYTECHNIQUE.

6. New Results

6.1. Massive mobile dense wireless networks

Keywords: *Scaling properties*, *analytical models*, *routing protocols*, *transport capacity*.

Participants: Cédric Adjih, Emmanuel Baccelli, Song-Yean Cho, Philippe Jacquet, Saoucène Mahfoudh, Pascale Minet, Paul Mühlethaler, Georges Rodolakis, Yasser Toor.

6.1.1. 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.

The great challenge is to find the good protocol and tunings that allow to adjust the delivery delay from zero to infinity in order to get a continuous increase in capacity. The challenge is two-sided: one has to keep the delivery delay between reasonable bounds and one has to consider realistic mobility models.
Existing protocols for Mobile Ad Hoc Networks (MANET) are highly efficient in routing data between mobile nodes that belong to the same connected component (cf. the protocols which have received the RFC status by the manet group of IETF). What about a disconnected network where source and destination may be located in two different connected components? In this case usual routing protocols drop packet due to host unreachable as no end-to-end route exists at that time.

A simple idea is to allow the router that has no available route to the destination to keep the packet in buffer until the conditions become more appropriate for forwarding. The forwarding conditions will change because of mobility: the router can move closer to the destination so that they belong to the same connected component and the packet can be delivered.

Indeed, the network may be continuously partitionned due to high mobility, and the traditional approach to allow a mobile node to wait for the network to be fully connected (i.e. form a unique component) or to wait to be in range of the destination may lead to unacceptable delays. Furthermore, concrete applications, such as Defence and Disaster-Relief, cannot always rely on such assumptions.

Nevertheless, even if the communicating nodes may never be within the same connected component, it is important to observe that a “communication path” may be available through time using intermediate nodes that are temporarily within reach of each other while moving, hence making such networks viable for critical applications. Depending on the nature of the environment, these networks are now commonly referred as Intermittently Connected MANET and Delay Tolerant Networks.
In between stands the problem of the fully connected betwork that forms a single connected component, but for which maintening full knowledge of the topology would simply make the network collapse under its huge control traffic. In fact this is the main problem that wireless network engineering has to face, in most experiments the generation of control traffic is the main source of disruption.

6.1.2. Scientific achievements

6.1.2.1. 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.

6.1.2.2. Time capacity and node mobility

We have defined a protocol that takes advantage of node mobility in a general way. In short the packet stay with its host router as long as the latter does not evade too fast from its next hop (computed via a shortest path protocol such as OLSR). In the way we understand “too fast” stands the tuning parameters we discussed above. There is no need to have node geographical location and to physically measure motion vector, since everything can be done via the analysis of the dynamic of neighborhood intersections. We analytically derived performance evaluation under random walk mobility models. We plan to simulate the protocol in a real mobility scenario. This algorithm has application in Intelligent Transport System.

6.1.2.3. 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.

6.1.2.4. 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 just started to work on a broadcast and unicast packet algorithms.

6.1.2.5. 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.

6.1.2.6. Network Coding

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). In [49], 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.

6.1.3. Collaborations

- Professor Bernard Mans, Macquarrie University, Sydney, Australia,
- TREC INRIA team,

6.2. New services and protocols

Participants: Cédric Adjih, Emmanuel Baccelli, Song-Yean Cho, Philippe Jacquet, Saoucène Mahfoudh, Amina Meraihi, Pascale Minet, Paul Mühlethaler, Georges Rodolakis, Farid Sayah, Yasser Toor.

6.2.1. Executive summary

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

In a wireless network, the set of neighbors which with one node can communicate depends on transmission range, and numerous factors, and in addition the transmission range is often lower than the interference range (the range within which a node prevents correct transmissions of other nodes). Thus bandwidth reservation, a crucial step of quality of service, is an important and difficult problem.

The services and protocols that need careful adaptation are

- Connectivity continuity
- Bandwidth reservation
- Delay routing
- Connectivity control
- Autoconfiguration
- Security
- Energy efficiency

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 optmization of overhead for mobile networks and the full internet legacy. It naturally provides path redundancy which accelerate link failure recovery.

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.
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 all connections are point to point. In this case multicast protocols that allows to gather all these point to point connections in a single flow is a need.

There are two classes of multicast protocols: the tree 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.

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 Connectedc 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.

Quality of service has become the central requirement that users expect from a network. High throughput, service continuity are critical issue for multimedia application over the wireless internet where the bandwidth is more scarce than in the wired world. 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.

6.2.2. Scientific achievements

6.2.2.1. Optimized Link State Routing (OLSR)

The routing protocol OLSR is universally known in the mobile wireless community (more than 475,000 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.

6.2.2.2. Bandwidth reservation in mobile ad hoc networks

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. This solution has been implemented on the MANET/OLSR demonstrator of CELAR (MoD).

6.2.2.3. Routing based on packet delay distribution in multihop ad hoc network

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.

6.2.2.4. 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, multicast group>. For each multicast group we have several trees. Notice that IGMPv3 [16] 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.

6.2.2.5. 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 delivery ratio. The overhead induced by the multicast protocol is given by the number of retransmissions per multicast packet. We have increased:

- the number of multicast groups,
- the number of sources,
- the number of clients in a group,
- the source rate,
- the number of network nodes,
- the mobility.

With these results, we can deduce the applicability domain of each multicast protocol studied: SMOLSR, MOLSR and MOST.

6.2.2.6. Theoretical upper bound

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.

6.2.2.7. Geo-broadcast in wireless sensor or ad hoc networks

The technique of Multipoint Relays (MPRs) has proved its efficiency to optimize network flooding in mobile ad hoc networks (MANETs) and wireless sensor networks. Indeed, the number of redundant retransmissions of a message broadcast in a wireless network is reduced by ensuring that only a subset of nodes selected as multipoint relays are allowed to forward the received packets.

We have designed efficient solutions for broadcasting in a geographical area of mobile ad hoc and sensor networks. A solution is constituted by two modules:

- the first one deals with MPR selection,
- the second one defines the strategy for forwarding the received information.

We have then studied an example of application in a sensor network structured in different subareas. Each subarea is controled by a robot in charge of replacing failed sensors. We have evaluated the benefit brought by our solution in this specific context.

6.2.2.8. Network coding

In traditional communication systems, nodes exchange data in packets, through relaying by intermediate nodes without modification of their content (routing). Seminal work from Ahlswede, Cai, Li and Yeung in has introduced the idea of network coding, whereby intermediate nodes are mixing information from different flows (different bits or different packets), for instance performing "exclusive or" between packets, before retransmitting them.

The Hipercom team is studying network coding specifically for MANET networks. It is mostly used as an efficient multicast/broadcast method (limiting the number of transmissions), and also as a reliable flooding mecanism. Hence, we are studying network coding in the context exclusively of energy-efficiency (and not capacity maximization).

We have proved theoretical results that extend previously obtained results. In another direction of work, we have designed a practical protocol to perform broadcast with network coding, DRAGONCAST in [36], [53] and [35], which builds on these theoretical results. The main advantages of DRAGONCAST are its energy-efficiency and its simplicity. We analyzed it by simulations and simple models; it successfully illustres how (and how well) energy-efficient broadcast with a simple method could be performed with network coding.

6.2.2.9. 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 auto-configuration 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.

6.2.2.10. Security in OLSR

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.

6.2.2.11. OLSR with metrics

In practical networks, one property of many networks is that wireless transmissions may be done with the same equipment but with different parameters, such as modulations (with various payloads), transmission power, etc...This is true, for instance, for 802.11 networks, where different modulations are standardized.

However in the common OLSR routing protocol, this is not addressed, since the view is a binary view of links, which are considered either symmetrical (and then equivalent) or not usuable.

The question is how to take into account this ability to transmit in several manners, so that routing (with OLSR) is performed efficiently. We have proposed in [50] and in [51], an extension of the OLSR routing protocol using metrics, that are well adapted to wireless networks with the characteristics of 802.11 networks.

6.2.2.12. Cross layer, sensor networks, energy efficiency

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;
- *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. Large benefits are expected.
- *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.

6.2.2.13. 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. To take into account residual node energy, the native selection of multipoint relays of OLSR is changed. It considers the weighted residual energy of the multipoint relay candidate and its 1-hop neighbors. The cost associated with a multipoint relay candidate represents the maximum transmission duration that can be sustained by this node. Each two-hop neighbor must be covered by the candidate of maximum cost. These new multipoint relays are called EMPRs. They are used to build energy efficient routes, whereas the native MPRs are used to optimize network flooding. No additional message is required in EOLSR. In order to select the EMPRs, the Hello messages include the residual energy of the sending node and of its one-hop neighbors. In order to compute the energy cost of a flow, we need to know the number of nodes up to two-hop of the node considered, assuming that interferences are limited to two hops. Hence, the TC (Topology Control) messages include the number of nodes belonging to the interference area of the TC originator.

As it has been shown that two-path routing is energy efficient, we compare EOLSR with a two-path source routing strategy: DL a two-path source routing with different links and DN a two path source routing with different nodes. As expected, native OLSR provides the smallest network lifetime. This shows that the selection of the shortest path is not sufficient to save energy. Concerning the two multipath source routing strategies, DN provides better results than DL. This is not surprising insofar as energy is dissipated per nodes and not per wireless link. Hence, DL that allows common nodes in the two paths can exhaust the energy of these common nodes more quickly. The main conclusion of these simulation runs is that EOLSR significantly outperforms DN and DL whatever the number of nodes. Moreover, the gain is increasing with the network size. EOLSR prolonges the network lifetime of 50% compared with OLSR for a network of 200 nodes. Notice that in the same conditions, DN prolonges the network lifetime of only 10%. Indeed, the two paths chosen by the source of the flow are used for all flow packets independently of the residual energy of these nodes. So the intermediates nodes exhaust their energy more quickly. This extensive performance evaluation allows us to conclude that EOLSR maximizes both network lifetime and the amount of data delivered.

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

6.2.2.14. Nodes 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. It is a localized and decentralized algorithm assigning time slots to nodes depending on their color. Any node stays awake only during its slots and the slots assigned to its neighbors, it sleeps the remaining time. SERENA is based on distributed three-hop coloring. The node's color is then mapped in time slot. Such a solution supports late node arrivals. We have chosen node coloring because, unlike link coloring, it enables broadcast transmissions. Moreover, the existence of radio interferences requires at least two hop coloring. If a receiver is allowed to immediately acknowledge the received transmission, three-hop coloring is needed.

A performance evaluation allows us to compare SERENA coloring algorithm with existing ones such as Distributed Largest First, denoted DLF, 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. For a network of 200 nodes with a density of 10, the number of rounds in DLF is 273, whereas it is only 145 with SERENA. Moerover, it turns out that the number of colors used by SERENA depends (i) strongly on the network density and (ii) weakly on the number of nodes.

Simulation results show that SERENA maximizes both network lifetime as well as the amount of data delivered to the application. Moreover SERENA improves efficiency in the the node energy consumption. 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.

The SERENA protocol will be implemented in the OCARI project. A strong cooperation with the MAC layer enables an efficient time slot allocation and an early detection of color conflicts caused by mobility. This cooperation improves the performances of SERENA in a network where bandwidth and energy are limited.

6.2.3. Collaborations

- Many contractual collaborations:
  - MoD (QoS, security, interconnection between the OLSR and OSPF routing domains),
  - Hitachi (Vehicular applications, OLSRv2),
  - OCARI project (QoS, cross layer, energy efficiency),
  - SARAH project (QoS, localization),
  - Com2react (vehicular applications, multicast),
  - STIC INRIA-Tunisian Universities: the team of Prof. Leila Saidane at ENSI (Performance improvement in a sensor network),
  - Luceor (OLSR with metrics).
- Non contractual:
  - BAE (OLSRv2),
  - Freie Universitaet (sensor networks, DHT).

6.3. Integration wireless and backbone

Participants: Cédric Adjih, Emmanuel Baccelli, Thomas Clausen, Song-Yean Cho, Philippe Jacquet, Saoucène Mahfoudh, Pascale Minet, Paul Mühlethaler, Georges Rodolakis, Farid Sayah, Yasser Toor.

6.3.1. Executive summary

We have the following vision: in the future mobile internet and static internet will have their core deeply intricated. This means that mobile ad hoc networks will be attached to the core network, form extension and even be part of it. For example in disaster area, a wireless network could replace the destroyed infrastructure and help to the emergency operations.

With this perspective items such as Autoconfiguration, Security are of crucial importance. However there is a potential conflict between a large population of fixed nodes based on ancient protocol and a smaller but more dynamic population based on new protocols. In the integration both population must cooperate in an hybrid protocol.

The difficulty is to build protocols that are as dynamic and efficient as MANET protocols but can support the legacy of the old and heavy internet protocols. The challenge is nevertheless achievable, because the dynamic part of the network needs less frequent updates from the fixed part of the network. Moreover the natural abondance of resource in the fixed part of the network allows it to support the more frequent updates from the mobile part.

OLSR has been found to be the natural best candidate for this challenge since it gathers dynamic and optimization with internet legacy.

6.3.2. Scientific achievements

6.3.2.1. Optimized Database exchange and check

The problem of unreliable broadcast and less frequent update is that a missing routing information information can lead to lasting problems (loops, disconnections). We have specified an integrity check of distributed databases. We have replaced the heavy check done in wired world that exchanges database headers line by line by a collective check based on signature broadcast and exchange. That way the routing database are synchronized more quickly and discrepant part identified with a logarithmic cost instead of a cost linear to the database size.

6.3.2.2. OSPF-MPR

The INRIA proposal is based on OLSR, in particular the optimization feature called MultiPoint Relay. The overhead reduction is similarly based on flooding reduction, and topology reduction. In particular OSPF-MPR supports optimized routing based on general additive metrics as in OSPF and adapt its topology reduction to those metrics. Compared to OLSR, OSPF-MPR has a feature called adjacency reduction inherited from OSPF, using broadcasted acknowledgement that enhances routing database synchronization. This feature is also optimized with MPR.

6.3.2.3. Gateway OSPF/OLSR

The MANET extension protocols being largely experimental, we have developped a software that enable 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).

6.3.3. Collaboration

We received support from MoD for this activity.

7. Contracts and Grants with Industry

7.1. CELAR

Participants: Cédric Adjih, Philippe Jacquet, Pascale Minet, Paul Mühlethaler, Amina Meraihi.

The CELAR (Centre d'Electronique de l'Armement, French MoD/DGA) contract has been notified in December 2007. It has a duration of 27 months. 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:

- OLSRv2: identification of the differences with the previous version and expected benefits;
- Multicast protocols: analysis and performance evaluation of three multicast protocols: SMOLSR, MOLSR and MOST;
- Autoconfiguration in IPv6: choice of a solution adpated to military applications;
- Dynamic routing over a hierarchical topology: when does a hierarchical routing outperforms a flat one?
- Adaptive routing on high frequency (HF) links;
- Merge of networks.

Three of them will lead to an implementation on a real platform comprising 18 nodes. Nodes are equipped with 802.11b cards and measurements tools on Linux. They implement the OLSR routing protocol. This testbed allows CELAR to make demonstrations with a real mobile ad-hoc network, and evaluate the potential benefits of such a network in military tactical applications, with a special focus on performances and reliability.

- OLSRv2,
- Autoconfiguration,
- Multicast.

This year, we have worked on Multicast protocols, Adaptive routing on high frequency (HF) links and the implementation of OLSRv2 on the MANET/OLSR demonstrator.

7.2. OCARI

Participants: Pascale Minet, Saoucène Mahfoudh.

The OCARI (Optimization of Ad hoc Communications in Industrial networks) project, funded by ANR, started in February 2007. It has a duration of 36 months. The industrial partners are EDF (coordinator), DCN and One-RF. The academic partners are LIMOS (Clermont Ferrand university), LATTIS (Toulouse university), LRI (Paris Sud university) and INRIA.

The OCARI project 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,
- Support of human walking speed mobility for some particular network nodes, (e.g. sinks),
- Support of IEC61804/EDDL and HART application layer.

The development of OCARI targets the following industrial applications:

- Real time centralized supervision of personal dose in nuclear power plants,
- Condition Based Maintenance of mechanical and electrical components in power plants as well as in warships,
- Environmental monitoring in and around power plants,
- Structure monitoring of hydroelectric dams.

To meet the requirements of supported applications (remote command of actuators, tele-diagnostic...), new solutions will be brought to manage several communication modes, ranging from deterministic data transfers to delay tolerant transfers. A key issue is how to adapt routing algorithms to the industrial environment, taking into account more particularly limited network resources (e.g.; bandwidth), node mobility and hostile environment reducing radio range.
The OCARI project aims at developing a wireless sensor communication module, based on IEEE 802.15.4 PHY layer and supporting EDDL and HART application layer. The INRIA contribution concerns more particularly energy efficient routing and nodes activity scheduling.

- The energy efficient extension of OLSR, called EOLSR, will be implemented on top of the MAC protocol defined by LATTIS and LIMOS. The MAC protocol is a variant of ZigBee ensuring some determinism and quality of service and allowing leave nodes (e.g. sensor, actuator) as well as router nodes to sleep. The EOLSR protocol avoids nodes with low residual energy and selects the routes minimizing the energy consumed by an end-to-end transmission. EMPRs (multipoint relays taking into account the residual energy) are used to build energy efficient routes. We have shown by simulations that EOLSR increases the network lifetime and outperforms multipath routing (both with different links and with different nodes). The specifications of the EOLSR protocol have been delivered to the industrial partners.
- SERENA, the protocol used to schedule router node activity, is based on three-hop coloring. It allows any node to sleep during the slots thaht are attributed neither to its color nor to its one-hop neighbors. SERENA contributes to a more efficient use of energy: less energy is spent in the idle and interference states; Hence, network lifetime is considerably increased. Specifications of SERENA adapted to the specific context of OCARI (i.e.; very limited bandwidth 250kbps, small size messages 127 bytes, limited memory and limited processing power) are in progress.

7.3. SARAH

Participants: Philippe Jacquet, Juan Antonio Cordero Fuertes.

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. The partners are ALCATEL, FT R&D, LIP6, LRI, LSIIT, LSR-IMAG, SNCF, ENST, INRIA.

7.4. RAF

Participants: Paul Muhlethaler, Khaldoun Al Agha.

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.
The partners are Thalès, Alcatel Lucent, EADS, IEF, INRIA, LRI, Sagem DS, and Supelec.
In this project INRIA is more particularly in charge of optimisation and performance evaluation of Ad Hoc networks devoted to security qnd rescue applications.
INRIA has compared the time division multiple access (TDMA) approachs where time slots are reserved within a radius of n-hop around the transmitter with conventional (Carrier Sense Multiple Access) CSMA protocol controlled by the carrier sense threshold. INRIA has studied the signal to interference and noise ratio (SINR) that is obtained by the two approaches. This study shows that on medium size networks it is difficult to obtain large SINR with a high probability with the TDMA approach whereas it is easy with the CSMA approach.
INRIA has also compared these two approaches in the classical outage model where a packet is received if its SINR is above a given threshold. With this model the TDMA approach offers a sigthly better performance in terms of global throughput than the CSMA approach. The path loss exponent can be changed without changing this result.
The TDMA approach and the CSMA approach are then compared in a model of dynamic coding idealized by Shannon's well-known law. In this model TDMA sigthly outperforms CSMA for every value of path loss exponent between 3 and 5.

7.5. MOBISIC

Participants: Philippe Jacquet, Emmanuel Baccelli.

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. The partners are THALES, ALCATEL, SAGEM, GEMALTO, BERTIN Technologies, EVITECH, SINOVIA, SODERN, CEA, INRIA.

7.6. EXPESHARE

Participant: Philippe Jacquet.

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. The partners are 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.

8. Dissemination

8.1. University teaching

Philippe Jacquet taught:

- in the MPRI MASTER(Paris) class : mobile ad hoc network/PeertoPeer networks (with Laurent Viennot),
- Ecole Polytechnique, Recitation Class : Foundation of computer science;
- at the EPITA school. Security in mobile and wireless networks;
- Master MISIC (Polytechnique) class: Telecommunication.

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 “Informatique Fondamentale et Applications” of the university of Marne-la-Vallée.

Participation of Paul Muhlethaler to Lessons "Ad hoc Networks", The 802.11 Standard and wireless Networkand for ENST B.

Thanks to the contacts created during the IETF meetings, we have started a fruitful close collaboration with Niigata University (prof. K. Mase) about mobile ad hoc networking. Common IETF drafts have been submitted. since buffer capacity might be limited on wireless routers.

Through common IETF activities with R. Wakikawa and K. Uehara, Hipercom has developped strong links with Keio University in Japan. This has recently been formalized through a "memo of understanding", between Hipercom and Keio University. Several joint academic publications as well as IETF publications have been the fruits of this collaboration on various subjects such as porting OLSR on BSD-ZEBRA, MANET-NEMO convergence, OLSR for IPv6.
This collaboration is also enabling Hipercom to take part in the WIDE consortium in Japan uniting Keio University (with J. Murai, the japanese Internet pioneer) and several industry heavy weights such as Hitachi, Mitsubishi, KDDI, NTT and other japanese universities and companies. This initiative is among other things organizing a large scale testing of OLSR on vehicles (with a prospect for testing OLSR on 1500 cars), which promises to be an extremely valuable experience for Hipercom, as no such scale study has been carried out to date.

Within the project STIC INRIA - Tunisian Universities entitled ‘Performance improvement in a sensor network by means of mobile robots’, Professor Leila Azouz Saidane from ENSI was invited by INRIA in July and December. Her four students Ines Korbi, Sahla Masmoudi, Nour Brinis and Olfa Ennar came at INRIA for a training in September or November. Pascale Minet was invited by ENSI in April and September and Saoucène Mahfoudh in December.

8.2. Participation to workshops, invitations

Philippe Jacquet was the PC chairman of the AofA conference, held in Juan-les-Pins, last June. This conference was organized by INRIA.
Philippe Jacquet belongs to the editorial board of the DMTCS journal.

Pascale Minet was jury member of the ’Habilitation à diriger des recherchres’ of Laurent George “Robustesse temporelle dans les systèmes embarqués et distribués”, University of Nantes, November 2008.

She was also reviewer of the PhD Thesis of:

- Noureddine Kettaf, "Mécanismes de contrôle de qualité de service dans les réseaux ad hoc", Université de Haute-Alsace, Colmar, May 2008.
- David Espes, "Protocoles de routage réactifs pour l'optimisation de bande passante et la garantie de délai dans les réseaux mobiles ad hoc", Universite Paul Sabatier, Toulouse, November 2008.
- Sébastien Linck, "Optimisation et adaptation des communications dans un réseau hétérogène", Université de Franche-Comté, Montbéliard, December 2008.
- Damien Masson, "Intégration des événements non périodiques dans les systèemes temps réel - Application à la gestion des événements dans la spécification temps réel pour Java", Université de Paris-Est, Marne-la-Vallée, December 2008.

Pascale Minet was program committee co-chair of the 16th international conference on Real-Time and Network Systems, RTNS 2008 in Rennes, October 2008.
She was member of the program committee of:

- HPCC'2008, International Conference on High Performance Computing and Communications, September 2008.
- ICCCN'2008, International Conference on Computer Communications and Networks, August 2008.
- IFIP Wireless Days, December 2008.
- JDIR'2008, 8èmes Journées Doctorales en Informatique et Réseaux, January 2008.
- Med-Hoc-Net'2008, 7th annual Mediterranean Ad-Hoc Networking conference, June 2008.
- PAEWN'2008, Int. workshop on Performance Analysis and Enhancement of Wireless Networks, April 2008.
- SERA'2008, Int. Conf. on Software Engineering Research & Applications, August 2008.
- SNPD'2008, 8th International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing, July 2008.
- SPECTS'2008, 2008 International Symposium on Performance Evaluation of Computer and Telecommunication Systems, July 2008.
- WNAS'2008, 2nd IFIP international conference on Wireless Networking Ad hoc and Sensor.

Besides these conferences, she was reviewer for the following international conferences:

- PIMRC 2008, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications,
- European Wireless 2008,
- ICECS'2008, 15th IEEE International Conference on Electronics, Circuits, and Systems.

Pascale Minet was also reviewer for the following journals:

- IEEE/ACM Transactions on Networking,
- IEEE Transactions on Industrial Informatics,
- IEEE Transactions on Parallel and Distributed Systems, TPDS,
- Computer Networks Journal, COMNET,
- Simulation Modelling Practice and Theory journal,
- Journal Of Interconnection Networks.

Paul Muhlethaler is an expert by the European Community for telecommunication projects.
Paul Muhlethaler was PhD Reviewer of Thierry Feuzeu Kwenkeu, "Extension de réseaux locaux Ethernet avec la commutation de label", University of Rennes, March 2007.

8.3. 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;
  - MANET: see the numerous contribtions of T. Clausen, P. Jacquet and C. Adjih;
  - OSPF: E. Baccelli is an important contributor;
  - NEMO: E. Baccelli takes an active part in this group.
- IEEE: HIPERCOM has pending patents with regard to 802.11;
- ETSI: Philippe Jacquet is the INRIA official contact;
- Car2Car: Paul Muhlethaler is the INRIA official contact;
- NATO: Pascale Minet made four presentations about OLSR and its extensions.

8.4. Associated teams and other international projects

The HIPERCOM project-team works with:

- University of Macquarie, Sidney, Australia: Prof. Bernard Mans: "Algorithmics for Extremely Mobile Wireless Networks",
- ENSI, Tunis, Tunisia: Prof. Leila Saidane: "Performance improvement in a sensor network by means of mobile robots".

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