

Research Activities in 4G Networks at INESC Porto

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Abstract — This paper gives an overview of the current research activities in mobile communications networks at INESC Porto, with emphasis on fourth generation (4G) networks and ambient networks. The main topics covered are the development of a generic link layer for heterogeneous networks, the automatic and dynamic creation of networks, including ad-hoc and multi-homing, mechanisms to provide Quality of Service (QoS) over wireless links, test and monitoring tools required to validate these networks, and emerging multicast solutions. A testbed is being deployed to support these research activities as well as the integration and demonstration of results with real services.

I. INTRODUCTION

The Communications Networks and Services group, which is integrated into the Telecommunications and Multimedia Unit at INESC Porto, has been active for more than fifteen years through the participation in a large number of European and national R&D projects, as well as in contracts with the industry and telecom operators. The main research topics addressed include broadband networks, with emphasis on ATM and at present on all-IP networks, protocol and service engineering (specification, validation, test and evaluation), resource management and Quality of Service (QoS) and, more recently, wireless and mobile communications.

This paper focus on the main research activities in mobile communications, which builds on and extends the experience of the group in all the above topics, while opening new directions of research in line with the current trends in fourth generation (4G) networks.

II. RESEARCH IN MOBILE COMMUNICATIONS

Mobile communications networks differ from fixed networks by a set of characteristics that include (1) mobility of the terminals, (2) properties of wireless links, which are characterized by variable bit rates and variable bit error ratios (BER), (3) low processing and memory capabilities of the terminals, and (4) low consumption requirements. Two important research areas are currently emerging in the mobile communications field: fourth generation (4G) networks and ambient networks.

4G networks are an extension of current mobile communications networks, such as GPRS and UMTS. Besides the assumptions made by GPRS and UMTS that Internet and mobile communications will evolve side by side, 4G introduces the concept that a mobile terminal will be

Always Best Connected (ABC) to the available networks. This is possible since a terminal may have multiple network interfaces, of different radio technologies, which are used according to the user requirements and, possibly, simultaneously. 4G also considers that all the information is conveyed as IP packets. Research problems include the support of mobility, routing, QoS and radio resource management, security, and traffic accounting. Ad-hoc and mobile networks, which will expand the coverage of the telecom operator networks, are also highly relevant topics of research, as well as those related with network planning, management and operation.

Ambient networks support, from the communications point of view, the concept of ambient intelligence. The latter is a vision of the future where people are immersed in the environment, which is sensible and reacts to their presence. Persons are expected to carry small devices, embedded in their clothes or even in their body and interconnected by means of personal area networks (PAN). Those devices will communicate over radio links to establish connections with neighbour networks. Communications may include aspects such as composition, security and mobility.

III. STRATEGY AND MAIN RESEARCH TOPICS

Research in Mobile Communications at INESC Porto is being carried out by a group of senior researchers and post-graduate students, mainly in the framework of EC funded R&D projects, thus continuing a strategy that has been pursued over the years with success. Five main lines of research are currently being explored: ad-hoc networking, generic link layer, QoS and congestion avoidance, testing and multicast.

A. Ad-hoc networking

In ad-hoc networking, the first aspect being addressed is the spontaneous formation of networks. Existing ad-hoc routing protocols are being studied and characterized in order to assess their adequacy for networks supporting multiple types of interfaces and devices, such as laptops and PDAs. Particularly interesting is the improvement of these protocols and solutions so that multipath, multicast and QoS may be used.

A second research topic is the integration of ad-hoc networks with infrastructure networks. In this context, address autoconfiguration and gateway discovery are hot issues, but the support of fast handover using these nodes, the node handover between ad-hoc and infrastructure mode and the adoption of multipaths are also being considered.

A third line of action is the definition of a new ad-hoc communication concept. It is based on the assumption that the computer is configured as in current networks, but simple

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signaling allows that when two computers or networks meet they can exchange information about routes, security and QoS and form a new network. Aspects such as mobility and multi-homing are also included.

B. Generic link layer

The generic link layer research line tries to unify the access to the various radio technologies that are relevant in 4G. Although IP could, in theory, be used for this purpose, there is a set of issues, including QoS, security and efficiency, for which the IP layer is not offering adequate answers. An intermediate layer, similar to Multiprotocol Label Switching (MPLS), but taking advantage of cross-layer mechanisms, is the solution being pursued.

On one hand this means that the IP layer can always find the same interface for configuring very different layer 2 technologies. Hence, this layer must provide additional functions, such as link detection and adaptation, as well as interoperation with fast handover mechanisms, so that mobility with QoS can be supported. For this purpose, the layer helps the handover by means of functions that first request resources and then book them.

In addition, this layer will also make communications more efficient. IP packets that carry voice are small, thus meaning that the packet header introduces high overhead; the solution points to the adoption of Forward Error Correction (FEC) and robust header compression techniques that may take advantage of cross-layer information and thus reduce the overhead.

Finally, security is another important issue in this layer. Traditional layer 3 or layer 4 security solutions do not work well with header compression; for this reason, new schemes that make use of existing layer 2 mechanisms need to be provided.

C. Quality of Service and congestion avoidance

In the Quality of Service research line, problems are addressed from two complementary points of view.

In the first one, a traditional approach is followed. It uses *DiffServ*, plus signaling adequate to mobility, combined with resource reservation at the access networks. The aim is developing a solution that enables the usage of *IntServ* like services in the access network, which can be deployed over heterogeneous layer 2 technologies and book resources for flows. New and more advanced radio resource management techniques are needed. *InterServ* must then be mapped into *DiffServ* in the core network; this requires the development of signaling to transport flow information and request resources and capable of working in highly mobile environments.

In the second one, it is assumed that networks only provide best effort services; the aim is the provision of acceptable levels of QoS, even in the presence of highly mobile nodes, which generate large amounts of real-time, non-congestion controlled traffic. The main objective is designing new congestion avoidance algorithms and signaling mechanisms that, in order to be useful, may need information available

from the lower layers, such as the current BER, the bandwidth in use or the queues lengths.

D. Testing

Testing is one of the strongest research lines, having matured over the years, covering both performance and behaviour aspects.

From the performance point of view, passive testing components that monitor traffic and model it as flows are being developed. Flows are assumed to be mobile, and the tools being developed need to be capable to follow them so that the network operator always has a correct view of the traffic and also understands whether the flow, when moving, still continues to receive adequate service.

On the other hand, active test components, which are used to estimate the available bandwidth between network entry and exit points, are also being investigated. This will help a source to decide whether new flows can be transported to the destination, in a network that only provides best effort services

From the behavior point of view, work is directed to automatic test generation derived from protocol specification. The protocol is modeled as in formal languages like SDL or Promela. High level formal languages based on state machines that communicate by means of queues and messages are used. The model obtained is then randomly explored so that a new message is selected and sent to an implementation of the protocol. The messages received by the implementation are then evaluated against the model which, in case the message is valid, selects another message to stimulate the implementation. The value of the method resides on the algorithm defined for selecting the next message/parameter to send and in the tool itself.

E. Multicast

Multicast and broadcast are considered as a horizontal issue and, as a rule, they are relevant in most of the other topics, namely in ad-hoc routing, QoS and security. Existing ad-hoc routing protocols are being extended in order to support multicast. As far as QoS, a new solution that allows the reservation of resources for multicast groups has been specified and implemented. Finally, security mechanisms that enable groups to access and decipher video and audio streams have been developed and are being improved.

IV. MOBILE COMMUNICATIONS TESTBED

A mobile communications testbed is being deployed with the main goal of providing the basic infrastructure and tools necessary to support advanced research in 4G networks. It constitutes the platform for integrating and demonstrating the innovative results of this research, as well as offering services to users, thus allowing the assessment of users' requirements in a real environment. The testbed was specified taking into account a number of requirements driven by the outlined research objectives.

In the first place, it includes heterogeneous layer 2 network technologies and offers a solution for integrating and abstracting the QoS mechanisms provided by each technology.

Two communication modes (infrastructure and ad-hoc) are supported. The infrastructure component is aimed at emulating 4G telecom networks; it includes access routers to which IP terminals are connected and provides mobility support by means of MIPv6 and fast handover, while QoS is negotiated and enabled by the QoS Abstraction Layer. The ad-hoc component is mainly used to demonstrate integration with infrastructure networks. It will also be used in Ambient Intelligence scenarios that provide ambient services with QoS requirements to terminals (PDAs and mobile phones) that communicate directly with each other, using multiple layer 2 technologies. Ad-hoc routing protocols and light QoS mechanisms (mainly for congestion avoidance) are currently being investigated for this purpose.

Finally, cross-layer mechanisms allow applications and intermediate network communication layers to adapt to the dynamics of wireless and mobile communications.

A prototype version of an ad-hoc network has already been implemented with the main purpose of creating a simple Ambient Intelligence scenario, capable of demonstrating its main concepts, such as the adaptation of the environment to the immersed elements, automatic service discovery and network auto-configuration. It is based on current wireless network technologies (WLAN 802.11 and Bluetooth) and offers services that adapt to the preferences and characteristics of the human users in the ambient, reacting to their presence.

The testbed will be progressively upgraded with new functions and services. While simple solutions have been used to demonstrate the basic concepts and features at an early stage of development, the network will be further enhanced with new services, including real-time ones, in more complex scenarios. Moreover, network automatic configuration mechanisms will be improved, QoS and IP macro and micro mobility will be introduced and ad-hoc multicast routing will be supported, thus allowing the fully integration between the infrastructure and the ad-hoc networks.

V. CONCLUSIONS

This paper described the current research activities in mobile communications networks at INESC Porto, focused on some of the most important and challenging topics in 4G networks.

This area is becoming quite appealing and rewarding not only from the research point of view but also because of the business opportunities it offers to all players in the field and the promise of new applications and more advanced services to users.

As a result of the research strategy adopted, the group has grown and matured and is quite active, both at national and international level. Other research groups are having similar

growth, thus meaning that in Portugal we are starting to reach the critical mass required to enable mobile communications to emerge as a relevant industry, mainly from the communications software point of view.

This has already been recognised and led recently to the creation of a thematic network on mobile communications, which integrates a number of institutions (academic, industry and operators) that decided to join efforts around common scientific and technical objectives.