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1999-05-01

IR-S3-SB-9960

In proceedings of
IEEE Vehicular Technology Conference

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AN APPROACH TO 4TH GENERATION WIRELESS INFRASTRUCTURES - SCENARIOS AND KEY RESEARCH ISSUES

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Abstract Whereas the development of telecommunication equipment and services moves at a fast pace, infrastructure deployment, in contrast, is a slow and costly process, demanding a long-range strategic perspective in decision making. As a consequence, R&D efforts in this area are concerned with problems on a time horizon of 10 years or more. Studying the feasibility and viability of various future infrastructure architectures and potential road-maps of their deployment is the focus of the 4th Generation Wireless Infrastructures (4GW) project within the strategic Personal Computing & Communication (PCC) program (1).

In attempting to realize the PCC vision *"Mobile Multimedia to all at today's prices for fixed telephony"*, a difficult problem arises. In contrast to process of solving engineering and business problems in current or imminent wireless systems, where system concepts, requirements and markets are reasonably well known, very little is known about these things over a 10 year horizon. The approach used in the project to tackle this problem, is to use various scenario techniques. Plausible scenarios, describing the telecommunication scene in 2010 are used to determine potential technological and other bottlenecks in order to find key areas for research in this field, is a very important element in these studies. Some of these scenarios are presented in this paper, together with some implications regarding bottlenecks and key research issues. The results are presented in terms of working assumptions (WA) used with the project. The WA's are also proposed to provide a framework for interrelating different research activities within PCC.

I. INTRODUCTION

Today's mobile communication systems are primarily designed to provide cost efficient wide area coverage for a rather limited number of users with moderate bandwidth demands (voice + low rate data). What the consumer of telecommunication services of tomorrow will expect to receive is not that clear. One may speculate that he will expect to get the same services in a wireless fashion as he receives from a fixed network, including services demanding (at least instantaneously) high bandwidths. The future users may on the other hand be willing to sacrifice functionality for the added value of mobility - mainly because he will hardly be using any other stationary telecommunication devices. Third generation mobile systems proposals such as UMTS and IMT-2000 interpret these requirements as providing mobile internet services, with up to 2 Mbit/s in certain areas, will only partially address these requirements. In order to enable the use of truly new and innovative multimedia services, one can expect that not only higher bandwidths need to be provided, but also that the cost should be comparable or even lower than in second and third generation systems.

Previous studies have identified key limiting factors as spectrum shortage, power consumption and infrastructure costs (2). Spectrum shortage is mainly due to interference from other users but also due to regulation and co-ordination with existing services. Equipment power supply technology is not expected to make substantial progress (i.e., only 1-2 orders of magnitude) in the next decade, thus power consumption has to be limited. Facing these limitations, it is not clear how these future services can be achieved by a straightforward extrapolation of 2G and 3G-technologies. Studying alternative technologies and architectures for such wireless access infrastructures will be necessary.

PCC (Personal Computing and Communication) is a national research program financed by the Swedish Foundation for Strategic Research (SSF) focusing on these issues (1). The 4th Generation Wireless Infrastructure (4GW) project is one of the five PCC projects concentrating on the infrastructural aspects pointed out above. The project aims at studying key problems in the architecture and deployment of future wireless access infrastructures required to realize the PCC Vision "*Mobile Multimedia to all at the same cost as today's fixed telephony*". Since the realization of this vision is expected to require much larger infrastructural investments, than could reasonably be expected in the next few years, the project focuses on the infrastructure deployed beyond 2010. It is therefore important to test the infrastructure proposal for feasibility with respect to technical, economical and social limitations, as well as studying the infrastructure deployment process.

The project work will thus have its focus on the key factors that are expected to limit the evolution of future wireless communication systems. The six 4GW work packages are covering topics from the physical to the network layer. The output of the project is a set of gradually refined proposals for an overall architecture. This includes architecture proposals for integration with fixed backbone networks, sketches of new air interfaces (if required), resource and mobility management schemes, deployment scenarios and integration with existing infrastructure components, leading applications and user groups and business models for infrastructure operation.

One important problem the project has faced is that it is extremely difficult to identify bottlenecks and key technical problems in a system that is neither existing, nor is the environment in which the system is deployed known. To remedy this, the project has momentarily widened its scope to set the project activities and goals against a background of converging telecommunication, data communication and distributed computing technologies. The chosen approach for this purpose has been to use scenario techniques to paint a more general picture of the telecom society in 2010 taking technical, economical and social aspects into account. From these descriptions we deduce some of the bottleneck problems that need to be addressed in infrastructure design and deployment research. In this paper we will mainly report from these scenario studies and describe their impact on our technical research. We also outline our current working assumptions (WA's) regarding wireless infrastructures in 2010.

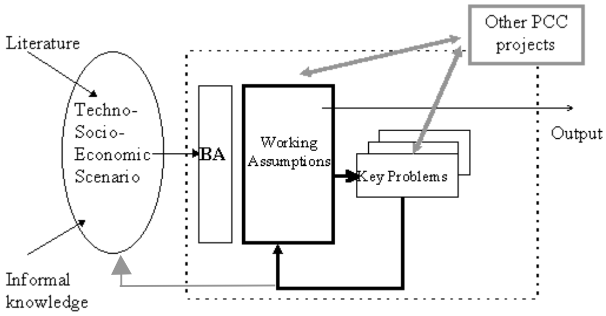

Figure 1: Process model for the 4GW project

II. CHOSEN APPROACH

The project process model is illustrated in Figure 1. The project work is focused around the working assumptions (WA's) that provide the common platform for interrelating, comparing and selecting research problems in the different work packages (WP's). The task of the WP is to derive and analyze key problems in the current set of WA's. The focus is on studying the feasibility of solving these problems as well as determining performance limits set due to these bottlenecks. The result will be used to modify the WA by changing the tradeoffs between various bottleneck areas. The WA's have to be consistent with a set of background assumptions (BA's) describing relevant parts of a techno-socio-economical (TSE) scenario for telecommunications in the time period 2010-2020. Such scenarios address issues like user behavior and lifestyle, evolution of fixed telecommunications markets and systems, evolving mobile terminal artifacts and their functionality and design, services requirements with the focus set marketability and lead user groups and projected availability of appropriate technology (hardware and reliable software).

In the long term perspective, the WA's will also influence the TSE scenarios, as indicated by the feedback arrow. Unlike the WA's, the BA's are not changed as frequently.

Scenarios have been used as a tool to initiate a research process within the 4GW project. During the last decade, scenarios have been widely spread as a managerial tool for promoting strategic thoughts within organizations (3). Scenarios have two essential purposes in the project: to change the way we think and to envision the future. They are interesting as envisions of thinkable futures; they give the possibility to test ideas and draw conclusions of many different developments. By nature such activities are speculations although they are systematically built, based on what is known today. By identifying trends and extrapolating them into the future a basis for strategic discussion can be made. Details about the methodology used can be found in (4).

III. SCENARIO SUMMARY

Scenarios are the outputs that reveal the essence of the world some decades ahead. By using different perspectives, three different scenarios as outlined below have been designed. More extensive, narrative descriptions of the scenarios are found in (5).

Anything Goes!

The diversity of telecommunications equipment has increased dramatically, as well as the possibilities of manufacturing cheap, compatible products. The manufacturing companies have become dominant in the telecom world. They advocate open de-facto standards, and use software solutions to create flexible, multi-standard equipment. Because of dramatic price reductions, both residential and business environments have wireless LAN solutions. They are operated by a multitude of operators, and the end-users have great freedom of choice in selecting where to purchase wireless services. Competition between operator and equipment provider is fierce and new wireless products and services appear at a high rate. Services and equipment are affordable for almost every-one in the industrialized world, which tends to narrow the social gaps in society.

Big brother

As more and more personal information is available in the information infrastructure, personal integrity issues become a major concern of the ordinary user. There is a widespread call for regulation and government intervention to ensure information integrity and secure networks. All citizens and companies whishing to deal with almost any aspect of computing and communication will need some kind of regulatory approval. In the private sphere most of the public information services use broadcasting.. The impact of this scenario is that the complexity of products and services increases and thus also the cost. Service, transport and equipment providers are reduced to a few large actors (brands) that, in the public eye, can be trusted. The development pace is slow and the number of wireless systems and operators is low.

Pocket computing

Pocket computing pictures a world where the technological development is fast, but due to economical and educational differences, the society is divided between those who can follow the development and those who cannot. Thus, some parts of the population have access to a multitude of advanced services, and other parts are using more simple services adapted to their needs. Service providers dominate the scene by providing the wide range of different services (that may include specialized hardware) tailored to various user groups. The mobile multimedia services focused mainly on the high-end consumer and business needs. Global solutions are available but much too expensive to be affordable by the low-end user. Cultural and educational differences between nation and different strata in society have also led to political instability and unrest.

IV. IMPLICATIONS

The scenarios point to a number of areas that are relevant for future infrastructure research. In the project we have identified a set of common working assumptions that are outlined below. A number of key research problems have been formulated that challenge and, if necessary, alter these working assumptions.

4GW Working Assumptions

Tele-presence

… is used to create virtual meetings between individuals and provides full stimulation of all sense required to give the illusion of actually being somewhere else - an illusion that cannot be distinguished from the "real thing". The bandwidth required for tele-presence is, with efficient data compression and fast sensory feedback, less than 100 Mbit/s. The data stream is mostly dominated by 180-degree stereo, high resolution, full motion video. Multiple party meetings is one of the major communication patterns foreseen for this application. Meeting processes will be mainly real-time.

Information anywhere, anytime...

…with virtually seamless connection to a wide range of information services is a key feature of the information infrastructure. Information access to large volumes of data, pictures, video etc is nearly instantaneous in small portable terminals. Compared to real-time meeting process, this application is less delay sensitive. Users can tolerate longer delays since the information is not real-time critical. Possibly high data rates are required for high volume data transfer applications such as video retrieval. The traffic pattern is highly asymmetric with 50/1 ratios or more, favoring the system-to-terminal links. Seamless virtual connections (creating the feeling of always being connected) is important for the users. Information provisioning is dominated by educational/recreational material.

Inter-machine communication…

…is an important application/service, ranging from simple maintenance routines (e.g. refrigerator telling repair shop that a failure has occured) to sophisticated massive data exchange (e.g. camera and PC/TV exchanging video/picture information). All cars, household and office equipment down to less than 20 US$ have wireless interface as standard feature.

Security is an indispensable feature….

…of the infrastructure. Data integrity and protection against unauthorized access are key features, providing reliable services for banking, electronic payment and handling of personal information. Schemes that reliably prevent unauthorized tracking of users and other intrusions in the private sphere are in operation.

One-stop-shopping...

Services are provided in a one-stop fashion ("turn-key") directly to the consumer at the point of sales. Services are immediately available when leaving the store. The store (information provider) takes full responsibility for the service as well as for the hardware/software provided, if any. We find a..

Non-homogeneous infrastructure…

…consisting of several switching fabrics and a multitude of physical media. All elements of significance are digital. The fixed backbone structure is dominated by connection-less packet switching (IP-style). Also the new air interfaces in wireless systems use packet switching technology. The wireless infrastructure consists uses a multitude of air interfaces, inherited from the wireless systems of the late 90's and early year of the new millennium. Among the newer, packet oriented millimeter wave wireless systems for the high data rates in the 5 and 60 GHz bands have emerged with data rates up to 100 Mbit/s that fit in the pocket. An overlaid architecture provides seamless, transparent internetworking, using all kinds of air interfaces.

Public and private access mixed.

Public Wireless access quality and bandwidth varies, where higher data rates are confined to dense urban areas, office environments (private/public systems) and homes (private systems). Operators/service providers provide partial coverage for non-real-time wideband (10 Mbit/s) information access in most public places ("info-kiosk", infostations), in public transportation. Rural area information access bandwidth is limited to 1 Mbit/s, but provides reasonable coverage along all main highways and villages of more than 100 inhabitants.

Ad-hoc, unlicensed operation dominates...

..and many actors will provide parts of the infrastructure. Ad-hoc networking (spontaneous deployment, self-planning) in unlicensed bands (the 5 and 60 GHz bands) plays an important role (the dominant role in the "pocket computing" and the "anything goes" scenarios) and compete fiercely with the existing traditional public operator which experience dwindling market shares. Techniques for efficient multi-operator (private/public) sharing of unlicensed spectrum have been developed. Ad-hoc structures, where the equipment of the users (companies or even individuals) provide part of the infrastructure, are adaptive to possible new communication patterns. Control of the new emerging ad-hoc networks (incl. routing, mobility etc.) is fully distributed and highly reliable.

Multimode access ports in public systems…

…with multiple access air interfaces are used to accommodate a wide range of terminals. Large operator systems use advanced wireless access ports that that self-configure or and use non-critical physical installation procedures to reduce cost. Adaptive antennas play an important role in the self-configuration function. Access ports (wireless gateways) in ad-hoc access systems are simple single mode/single air interface devices. The cost of access port hardware in these systems is negligible in comparison with the cost of planning and physical installation.

Terminals….

..exhibit a large range of bandwidths, from less than 10kbit/s (e.g. simple appliances) to 100 Mbit/s (tele-presence terminals). Battery life for personal terminals will last at least for one week. Battery capacity/weight/volume ratios are up one order of magnitude compared with today's. Terminals in the 5 and 60 GHz range use advanced adaptive antennas. Terminals are either multi-mode, multi-function terminals (as in the "anything goes" scenario), or single-purpose, cheap terminals designed solely for a specific service ("pocket computing") or function specific (e.g. receive only).

Some Key Research Issues

One-stop shopping - terminal & service adaptability:

Since the user wants his services available on the spot, he is not willing to manually configuring his hardware devices and network services. This has to be done by the terminal devices themselves. The mobility and automatic adaptation to various standards and infrastructures that provide different bandwidths at different delays, opens up a wide area of research. There are questions on how to most efficiently adapt to new conditions (networks, bandwidth etc.), when to switch between systems and which layer should be responsible for different functions (6). Security issues in these environments represent major challenges.

Unlicenced public operation

Can multiple operators compete effectively (to the benefit of the consumer) without fixed frequency allocations? Are there technical solutions to this effect?

Support for new and more complex services

Telepresence applications provide a major challenge in wireless systems. Multicasting will play an important role in this and other meeting support-type services. Local, physical multicasting has also the potential to make vast improvements in spectrum efficiency.

Infrastructure deployment strategies - the business models

The high bandwidths projected in several of the WA's will require a dense and potentially costly infrastructure. What are the actors on the infrastructure market? Is the business volume 2010 sufficient to support an infrastructure that fulfils the PCC vision requirements? Will there be an evolutionary path along which money can be made for the involved players? (7).

Self-configuring ad-hoc networks

One interesting possibility to bring costs down (as implied by the "Anything goes" scenario) is that the users play the role of an "wireless operator" in his local surroundings. He may install his own low cost base stations where he needs them and where space and network connections are available. This calls for techniques that automate configuration, detection of other devices, creation of ad-hoc networks and management of the radio spectrum should be allocated. Adaptive antennas and efficient modulation techniques play important roles in this process.

V. CONCLUSIONS & FUTURE WORK

The process to find key issues in the 4th Generation Wireless Infrastructure has been presented. The objective and the motivation has put pressure on the 4GW group to begin such a process. Using a scenario based approach, the work resulted in three major scenarios describing possible "telecom futures". Key technical & economical research issues were derived and the project working assumptions. Potential futures have been briefly presented and a mix of them should be the most likely.

In addition, the scenario activities have provided additional benefits to the project, as they have become a very efficient way of starting a thought process of the participants, thus creating an much better awareness of the environment in which a research project is set. Strong interfaces between the WP's have been developed where both the technical information flow and the research responsibilities tie the members to the 4GW group together. The scenario work has also provided more confidence that the 4GW group works on the right problems. The scenarios have gained acceptance and created discussions within the PCC program, where they serve as a common platform for discussion of future systems and architectures.

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