Chapter 6: SERVICES, OPTIMIZATION, AND ECONOMIC ASPECTS

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6.1 Introduction

Future broadband wireless services will involve a range of different technologies, all with varying characteristics. These differences can influence significantly how a service is defined and deployed as well as how it is commercially offered to customers. Key technologies and services that will influence and shape the future broadband telecommunication market include WiFi services based on IEEE 802.11 standards, enhanced UMTS (Universal Mobile Telecommunication System) services, mobile grid services, incoming call handling services, and finally alternative approaches to broadband access such as high aerial platforms. Each of these technologies and services has unique requirements in terms of deployment and management.

Commercial offerings of value-added telecommunication services require appropriate support mechanisms, since the wired and wireless Internet design principles and architecture were originally not concerned with commercialization. These commercialization support mechanisms involve typical elements of business transactions, such as *Authentication, Authorization, Accounting, Auditing, and Charging* (A4C), but also automated contract formation procedures. In addition to requirements from the provider-side, there are also new requirements from the user-side. Wireless service users today seek greater choice and customization in accessing telecommunications services. This creates the need for user-controlled flexibility in service delivery, including full portability freedom. Requirements from both the provider and the customer side will shape new business models and their corresponding support mechanisms in terms of A4C.

Another key aspect in service definition and deployment is the efficient utilization of network resources, which are much more limited in mobile and wireless technologies compared to wired technologies. On one hand, efficient utilization should consider cost and revenue aspects, which is necessary to make a service offering profitable. On the other hand, efficient utilization should consider requirements from the user and application side.

This chapter addresses in more detail the above issues, highlighting both differences and special needs for various mobile and wireless technologies and services, but also identifying requirements of a uniform framework and architecture to provide multiple services. Section 6.2 discusses the definition and deployment of various mobile and wireless services. Section 6.3 discusses business aspects, in addition to A4C issues as well as charging and billing mechanisms. Finally, Section 6.4 investigates mobile and wireless networks, based on user/application requirements and cost/revenue aspects.

6.2 Services and Deployment Scenarios

Services determine the key concept with which the set of offerings from a provider to users are described. However, these services vary in specific characteristics as well as technologies, and any approach for the commercialization of such services needs to take into account these differences. In this section services under consideration include WiFi services, enhanced UMTS services, mobile grid services, and broadband wireless access. Before these services and their economic aspects are discussed in more detail, the underlying principle of contracts for value-added services in the Internet are described to ensure that the legal grounds for a commercialization can be laid undoubtedly.

6.2.1 Contract Formation for Commercial Value-added Services

Commercial offerings of value-added electronic services, especially in the wireless and wired Internet, ask for the design and implementation of respective commercialization support mechanisms, since Internet design principles were originally not concerned with commercialization, but with military and research purposes only. These commercialization support mechanisms involve typical elements of business transactions, such as A4C (see Section 6.3.4) [Has07], [Inf04], [TD(05)042]. Their range is determined by commerce law, aiming at legal compliance in business transactions. Since commercial offerings are based on contracts, not only do the aforementioned support mechanisms, but also the respective process of contract formation is required to be compliant with commerce law, and in particular with contract law determinations.

When considering bilateral contracts for commercial services in the wireless and wired Internet, contractual parties consist of a service provider and a service customer. Since the Internet is a global infrastructure, the service provider and service customer might be located in different locations. In case parties reside in different legal domains, which are typically territories, the rules laid down by private international law determine the court that has jurisdiction and the state law that need to be applied to the respective contract. In contrast to legal determinations, which are bound in general to a geographically limited area, the Internet lacks a reliable notion of location, which becomes even more unreliable for wireless services, which can include roaming users.

This fundamental design gap between territoriality in legal domains and location un-aware organizational domains of the Internet constitutes the prime menace to legal compliance in the provision of commercial value-added Internet services. Due to a high complexity level in procedural matters to form contracts in an international context and due to wide-ranging implications—basically to any contract type applicable to commercial Internet services—, technical mechanisms for legal compliance in contract formation for such services need to address a set of key specific challenges [Wal07]:

- Formalization of private international law procedures that are relevant to the respective set of electronic contracts applicable to those value-added service categories considered.
- Determination of a mapping relation between a given end-system located in an Autonomous System (AS)—an organizational domain in the Internet—and a legal domain.
- Guarantee of stable communication paths between two given end-systems representing involved contractual parties.

The formalization of private international law procedures is required with respect to an increased level of automation. Nowadays, these procedures include human interaction in many areas. This holds true in particular for conflicts arising from concluded contracts. Even though conflict settlement is not considered as a target for automation in this specific context, the respective private international law rules need to be reflected in contract formation phase. For instance, contracts often include a so-called choice of law clause, in which the applicable state law for a given contract is explicitly expressed. In a conflict case, a court with jurisdiction will conduct a so-called characterization of the business relation expressed by the contract in consideration. This characterization embraces a list of criteria to determine how closely potential state laws are connected with that business relation. A choice of law clause is one of these connecting factors, but not the only one. Hence, it is important to consider the full set of connecting factors when concluding a contract.

Automated contract formation procedures need to be modeled in a formalized way, such as by means of finite state machines. Even though rules of private international law, in theory, should produce a comparable outcome independent from the specific court conducting a characterization, in practice, these procedures are characterized by ambiguity resulting from a certain leeway in taking actions. This leads firstly to the conclusion that formal contract formation procedure modeling needs to be limited to a well defined range of services to be considered, and with that, to a well defined range of contract types to be considered. Secondly, the range of contractual procedures determined needs to be based on documented assumptions, which are supposed to reflect standard cases, that is, cases that can be modeled for automation so that the outcome of a potential characterization is likely to be deterministic and that human interaction is not needed.

While the formalization of private international law procedures determines the key area of work to achieve legal compliance in contract formation, those challenges mentioned with respect to mapping end-systems to geographic location and stable communication paths constitute both technical prerequisites to be in place. In analogy to those practical limitations envisaged for procedure automation, a mapping relation between end-systems in the Internet and geographic location is bound by definition to a certain upper level of information reliability and granularity. Since the Internet lacks a direct notion of geographic location, gaining geographic location information from any Internet end-system can be an approximation only. Nevertheless, the information, where contractual parties—each represented by the respective end systems in the Internet—is located, is essential for any contract to be concluded. Consequently, a technical solution addressing this issue is required to provide an approximation that is sufficiently reliable for a given contract, possibly by combining not only a single, but several techniques for estimating geographic locations of involved end-systems.

A guarantee on stable communication paths between two end-systems in the Internet may or may not be required for a given contract. Hence, this challenge is dependent on specific contract formation scenarios. For instance, contractual terms expressed in a *Service Level Agreement* (SLA) might foresee restrictions on data protection. Unless data communication is encrypted, it is of importance to respect agreed upon data protection determinations not only on the respective end-systems, but also on the path data taken when conveyed between these end-systems. Data, thus, needs to be exchanged on pre-defined paths that do not include conveyance through unwanted legal domains. An unwanted legal domain in this context is characterized as to inflict with those data protection determinations appointed in the contract of consideration. Encrypting data by default might not be a viable alternative in any configuration as there might be legal export restrictions on encryption to be considered.

6.2.2 WiFi Services in Future 4G Networks

The technical advances in digitalization and the progressive price reduction on processing capacity have stimulated the development of several waves of wireless technologies oriented to personal communications along the last decade. Starting from 2G technologies, new generation technologies referred as 2.5G and 3G comprising data services are now mature and are entering into the market steered by cellular operators that firstly succeeded in 2G technologies. The expected increase of wireless bandwidth in 3G will allow the use of portable devices for accessing advanced services, and machine-to-machine wireless communications.

The evolution of this third cellular generation, 4G networks, is not usually viewed as an improvement of existing 3G cellular technologies, but as a framework where diverse wireless and fixed technologies will cooperate in order to provide ubiquitous wireless broadband services, adapting the combination of different access technologies in each session to the bandwidth and QoS required by the different applications. The *IP Multimedia Subsystem* (IMS) architecture defined by 3GPP [Cam04] is the current candidate to orchestrate this wireless technology and market actors mix. This architecture has different planes for transport, control, and services, in order to coordinate the technology selection and service provisioning for each communication transaction in a multi-provider and multi-technology context.

Among different wireless technologies to be used in the 4G networks, existing 3G networks (based on UMTS and WCDMA – Wideband Code Division Multiple Access), HSDPA (High Speed Downlink Packet Access), WiFi, WiMAX, and Flash-OFDM (Orthogonal Frequency Division Multiplexing) are the ones most likely to be used. Depending on the context, these technologies can be combined in order to exploit the strong points of each technology, such as wide coverage, suitability in rural environments, and bandwidth availability.

WiFi will surely play a key role in the 4G context, due to its unique characteristics in the family of wireless technologies. First of all, WiFi is now the most widespread wireless access technology in terminal equipment, being a must for laptops, widely adopted in PDAs, and increasingly included in dual 3G-WiFi smart phones. In terms of bandwidth, WiFi offers now 54 Mbps of nominal speed (802.11g/a) and the new 802.11n standard will reach up to 100 Mbps. Even considering the useful information bit-rate in real conditions, the bandwidth is higher than the last UMTS/WCDMA evolution, HSDPA, accounting for nominal 14 Mbps of maximum transfer rate.

WiFi drawbacks are mainly centred on the difficulty to assure QoS features, and the unavailability of integral national widespread coverage, as it is the case for 3G cellular technologies. Although existing QoS deficiencies can be solved with the traffic prioritization extension for WiFi (IEEE 802.11e and on-going work on this topic [TD(06)012]), the problem associated with the non-integral coverage is intrinsic to the WiFi deployment model and it is not expected to reach coverage comparable to 3G technologies, but to cover hotspots, areas, and parts of cities controlled by different actors under different commercialization models ranging for free access, to prepaid cards, or packaged services combined with 3G or fixed based services.

Taking into account special WiFi technical and business models characteristics [TD(06)019], it is presumed that, in the 4G context, due to is bandwidth features this technology will support regular web browsing, email services, and other Internet services not so sensitive to QoS.

In the medium term, WiFi can also act as an opportunistic access technology for transmitting voice, using VoIP (Voice over IP) in a seamless way for services provided by cellular operators supporting the communication on their own hotspots or third-party ones under roaming agreements. In the short term, the unavailability of hand-off features and the immaturity of roaming agreements and QoS mechanisms, will limit the voice transmission to the use of Skype, Vonage and other VoIP service providers under a nomadic scheme, not fully mobile, with poor QoS characteristics, but favourable cost features for the users gaining access to free or flat-fee hotspots.

For WiFi, it is simple to obtain location information based on the connecting access point position for each session, with a precision between 30 and 200 m, depending on the access point coverage. Although this location information can be obtained with other wireless technologies such as 3G, it is controlled and administered by cellular operators. The low cost for WiFi access points allows the retail commerce, hotels, municipalities, and other small actors to deploy WiFi hotspots and use this location information to provide context-aware services (e.g., special offers, promotional videos, tourist or transport information) for connected users.

Municipalities and other organizations will also benefit from WiFi metropolitan or wide area networks through improved productivity of mobile workers using a public owned network for police, firemen, and other municipal officers, and access to security cameras and remote control systems, which is not economically or technically feasible using fixed networks or cellular technologies.

Finally, considering that most of all telecommunication services, including voice, are used at work and home, and that in both premises WiFi access points are usually used for deploying small wireless local area networks, in many cases these WiFi access points can be used as the preferred access technology (seamless or user-aware, controlled by cellular or fixed operator, or directly by the user) in order to save scarce resources or reduce the communication bill.

Depending on the involvement of cellular operators in 4G heterogeneous networks and the success of non-vertical WiFi service models controlled by alternative actors such as municipalities, user communities, and retail commerce, these services will be managed by traditional wireless operators or other more distributed actors [Ver06]. In the European case, cellular operators will play a key role in integrating WiFi in their cellular networks, and will use this technology coordinated with 3G and HSDPA in a seamless way via IMS in order to receive profit from advantages of each one according to the location and services demand. In the USA, where the cellular market is more fragmented and municipalities, users' communities, retail commerce hotspots, and WiFi-based wireless service providers are more active, the 4G development models will be focused more on distributed user-driven and cooperative deployments. In both cases, WiFi will play a key role as wireless access technology in customer premises (work and home) combined with UMTS/WCDMA and HSDPA for accessing services in locations where no WiFi hotspots are available or where in-motion connectivity is needed to provide a full coverage 4G environment.

6.2.3 Enhanced UMTS Services

An overview of *Enhanced UMTS* (E-UMTS) deployment scenarios and supported services is presented next, based on current views of relevant players, users and operators [TD(05)006], [Fer05]. Deployment and mobility scenarios include the expected population density and the usage of a service mix for several environments. A number of nearly thirty applications are considered. In consequence, a reduced set of applications is purposed for simulations use and scenarios are defined with a selection of the most relevant applications (see Table 6.1).

Applications Usage [%]	R_b [kb/s]	OFF	BCC	URB/VEH
Sound				
Voice (VOI)	12.2	25.0	27.0	42.0
High Interactive Multimedia				
Video-telephony (VTE)	128	15.0	16.0	16.0
Narrowband				
Multimedia Web Browsing (MWB)	384	20.0	26.0	18.5
Wideband				
Instant Messaging for Multimedia (IMM)	1024	25.0		
Assistance in Travel (ATR)	1660			23.5
HD Video telephony (HDT)	2048		31.0	
Broadband				
Wireless LAN Interconnection (WLI)	12780	15.0	-	-
Density Factor (users / m^2)		0.150	0.031	0.012

Table 6.1. Proposal for applications usage in each deployment scenario: office (OFF), business city center (BCC), and urban/vehicular (URB/VEH).

Additionally, E-UMTS traffic generation and activity models, based on population and service penetration values, are also described and characterized. ON/OFF states of the models are characterized by appropriate statistical distributions and parameters (see Table 6.2). Further details on traffic source models and their parameters are given in [ETSI98].

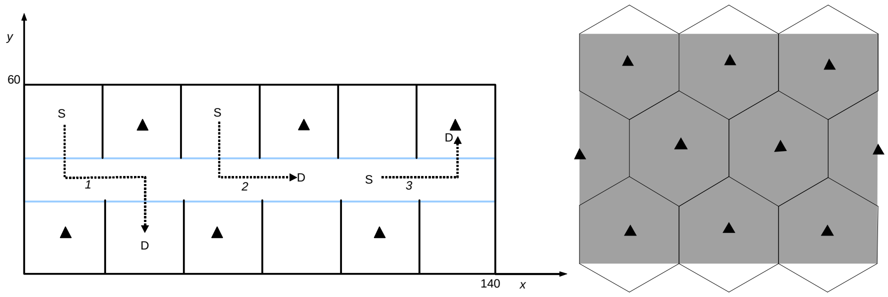
Applications	Active state (ON)			Inctive state (OFF)	
	Avg.[s]	Filesize[KB]	Distrib.	Avg.[s]	Distrib.

VOI	1.4	2.14	Expon.	1.7	Expon.
VTE	τ			0	
MWB	5	240	Pareto	13	Pareto
IMM	5	640	Weibull	90	Pareto
ATR	60	11520	Weibull	14	Pareto
HDT	τ			0	
WLI	5	7988	Weibull	1	Pareto

Table 6.2. Application activity parameters.

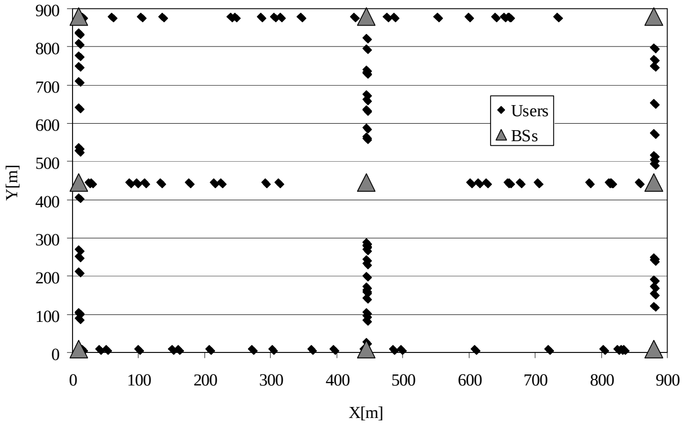
6.2.3.1 Topologies and Mobility

Each simulation scenario is defined by a variety of parameters, including traffic, propagation, and mobility models as well as topologies and user population. Furthermore, each scenario corresponds to a specific operating environment. The three simulated environments are the Office environment (OFF), the Urban/Vehicular environment (URB/VEH), and the Business City Center environment (BCC). The topologies are presented in Fig. 6.1.



a) Office

b) Urban



c) BCC

Fig. 6.1. Topologies considered (triangles represent base stations (BSs)).

6.2.3.2 Office (OFF) Scenario

In an office environment users are stationary most of the time. When they move they move towards a specific destination, which can be randomly chosen. Source and destination positions are either in an office room or a corridor. Therefore, the chosen path is either along the x or the y axis. Several parameters may be specified, such as the ratio of room situated mobile terminals to the corridor situated mobile terminals at any time, the average time in an office room and the corresponding average time in the corridor, the mobile speed, and the average distance between source and destination. The mobility model used for the office environment scenario is the Random-Waypoint mobility model (Section 4.2). The model defines a pattern of movements for each user individually. In this pattern, each mobile node is assigned a pause time. Every node waits for the time specified as the pause time, and then chooses a random location on the map and heads toward that location with a fixed speed of 3 km/h (0.83 m/s), a typical pedestrian speed.

The topology of the OFF scenario consists of several pico-cells distributed in a floor of 140x60 m according to Fig. 6.1. Offices are separated by a corridor of 5 m width and have a height of 3 m. As the cell radius increases or decreases, the number of cells decreases or increases accordingly. The topology with a cell radius of 20 m is illustrated in Fig. 6.1(a).

6.2.3.3 Urban/Vehicular (URB/VEH) Scenario

In an urban environment mobile devices move with higher speeds, according to a pseudorandom mobility model. Position updates are not as often as in the Business City Center due to the higher speeds. As an example, the positions may be updated every twenty meters. Parameters that could be specified are: the average speed, the probability to change direction at a position update, the maximal angle for this change of direction.

The mobility model used for the urban environment is the Gauss-Markov mobility model. The pattern is confined within the predefined grid area. The Gauss-Markov model implemented is defined to be between the random walk (slow speeds) and the fluid flow (very high speeds) models. The two models, random walk and fluid flow are labeled as extremes. Most of the nodes move somewhere in-between those speeds. Parameters for the Gauss-Markov model include the mobile speed at 50 km/h (13.89 m/s), and a random seed, a number that is fed into a random number generator, as this model aims to assign pseudorandom paths to the mobile users.

The topology consists out of several base stations, using tri-sectored antennas. A tri-sectored antenna consists of three 120-degree angle sectors in each Node B, allowing for 360-degree angle coverage and up to three times the capacity of an omni-antenna. A topology with cell radius equal to 439m is presented in Fig. 6.1(b).

6.2.3.4 BCC Scenario

In a Business City Centre environment, mobile devices move along streets and may turn at crossroads with a given probability, see Fig. 6.1(c). Positions are updated relatively often, typically every five meters, since this environment typically involves pedestrian speeds. At each position update, there could be a speed change according to a given probability. Several parameters may be specified such as the average speed and the minimum speed, and the probabilities to turn or to change speed.

The mobility model used for the Business City Centre environment is the Manhattan Grid mobility model. The Manhattan Grid model specifies that mobile nodes move only on predefined paths along a Manhattan grid i.e., parallel to either the x- or the y- direction. Since only pedestrians are considered, the user speed is set here again as in the Office environment to equal 3 km/h or 0.83 m/s. Users move on roads and at each crossroad they have a 0.5 probability to turn (0.25 to turn left and 0.25 to turn right) and a 0.5 probability to keep walking straight.

The BCC topology consists out of 9 micro cells, which are arranged as a grid with building blocks and crossroads, Fig. 6.1(c). The Node Bs are located outside the buildings in one of the corners as shown in Fig. 6.1(c).

The models and scenarios presented in this section where used to carry out simulations, where the E-UMTS system capacity was determined while guaranteeing a given degree of service (see Section 3.3). Using the results found for system capacity, Section 6.4.1 investigates a network optimisation problem based on a cost/revenue model.

6.2.4 Consumer-oriented Incoming Call Connection Service for Future Ubiquitous Consumer Wireless World

The wireless telecommunications market today is seeing an evolution towards a *Ubiquitous Consumer Wireless World* (UCWW) [O'Dr07] established on the *Consumer-centric Business Model* (CBM) [O'Dr04], an alternative to the traditional *Subscriber-centric Business Model* (SBM), (see Section 6.3.1). UCWW is technologically evolutionary in that the many different access network technologies (e.g., WiFi, UMTS, HSDPA, EVDO – Evolution-Data Optimized, WiMAX) will more easily coexist and complement each other in different areas. Mobile terminals' multi-mode capability will continue to increase, their 'intelligence' in many ways will multiply, and ever higher reconfigurability to accommodate various transport technologies will be the norm. Nonetheless UCWW will bring revolutionary changes and challenges on the wireless business front, e.g., greatly increased market openness for new Access Network Providers (ANPs) and Teleservice Providers (TSPs). Competition to the benefit of users will increase, e.g., in both traditional Internet and multimedia service markets. Users will pay for the services through trusted Third-Party Authentication, Authorization, and Accounting Service Providers [TD(05)041], using reliable and secure charging and billing mechanisms (see Section 6.3).

The consumer-oriented Incoming Call Connection (CBM-ICC) service [Wan07] is one of the new UCWW technologies and business opportunities. It aims at providing an open autonomous call control and mobility mechanism, partially controlled by the user and allowing him/her to dynamically associate with a number of access networks simultaneously and heterogeneously. Through the CBM-ICC service, users would choose the best access network for each particular type of incoming call according to the current context in order to better meet their subjective 'Always Best Connected and best Served' (ABC&S) requirements [O'Dr06].

The key innovation for the new emerging CBM-ICC service approach is a *personal IPv6 address* [Gan07] – a globally unique, permanent, and network-independent identifier used by its owner (user) across access networks for ICC and other services. With this address, the user can simultaneously accept different incoming calls (e.g., VoIP, instant messages, etc.) through different access networks by the help of new, independent, extra-ANP Incoming Call Connection Service Providers (ICC-SPs) by means of a universal CIM[1] card [Gan07].

A *Contact Address Identifier* (CAI) is defined as a public identifier, accessible in various ways, such as business cards, personal web pages, and public directories. A temporal *Contact Address* (CA) is assigned to the callee by the ANP chosen for a particular ICC. The ICC-SP maps the CAI to the appropriate CA and makes provisions for establishing the ICC session. *Network Address Translation* (NAT) is used by the ANP to map between the globally routable CA and the locally used (within ANP domain) personal IPv6 address in both directions of communication.

6.2.4.1 Benefits of using the consumer-oriented ICC service:

1. The traditional SBM-based ICC service is not flexible enough to support heterogeneous ANPs. Mobile users are associated with a unique (telephone) number assigned by the home ANP. All communications services are received through home ANPs and charges/tariffs levied by them according to their pricing model. Flexibility to receive some communications services from one ANP and others – from other ANPs is not available to users. However this flexibility is a natural and understandable consumer-user desire, and exists in most other markets. The only way for a user to be multi-homed today is to buy multiple SIM cards and swap between them within a single mobile handset or to use multiple handsets. This however causes a problem when an incoming call is delivered to a SIM card not currently in use. A key benefit of the CBM-ICC service is the better use of multiple and heterogeneous ANPs, in that the user may be truly *multi-homed* and can *dynamically associate* with more than one access network simultaneously. This is possible through one CIM[2] card. Hence the need of having multiple SIM cards as in the SBM-ICC service is eliminated. One typical example of CBM-ICC service is to use one access network (e.g., WiFi) for personal/family incoming calls satisfactorily matching economic and QoS profile, and another access network (e.g., UMTS) for business calls requiring the best QoS available.
2. Roaming in the traditional SBM-ICC approach is complex and costly. The unique relationship with the home ANP guarantees that all incoming calls are forwarded to this ANP first. But the roaming support in fact consists of at least one other ANP, whose network the user is currently roaming in. Service Level Agreements for roaming have to be in place beforehand between the home ANP and the foreign ANPs. While this infrastructure adds costs to receiving calls while roaming, present roaming tariffs are generally perceived as significantly higher than the actual costs of providing the roaming service. The CBM-ICC approach can *better support roaming* and even can *eliminate the roaming*

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[1] CIM (Consumer Identity Module) analogous to SIM card but based on CBM.

costs because users will appear always as ‘local’ to each ANP from whom they receive communications services. There are no ‘home ANPs’. All incoming calls go directly to ICC-SP, who manages their ‘re-direction’ to the current ANP(s) preferred by the callee.

3. The traditional SBM-ICC service only supports limited advance call control. However, there is an increasing trend for users to demand more flexible personalized incoming call management. The provision of *flexible and personalized Intelligent Call Management*, a key benefit of CBM-ICC service, will enable incoming calls to be handled and managed on the basis of access, filtering, and redirection policies pre-defined and/or dynamically defined by users (callees) according to different caller types and callee roles, callee/caller location, callee preferences, time/day/week configurations, etc.
4. Last but not least, the CBM-ICC service can introduce *new and open business environments* as it can be provided from outside the access network providers and independently of them. Thus it facilitates *easy market entrance* for CBM-ICC service providers and generally *increased competitiveness* among access network providers and teleservice providers, which will yield greater open-market economic benefits to consumers.

6.2.5 Mobile Grid Services

Grid resources are traditionally fixed resources managed by a single organization or an administrative authority[2] to provide for high performance computational services, e.g., for climate modelling, image analysis, and bio-medical simulations. Today, new types of services, e.g., semantics-driven Web services and audio video conferencing, which generate high traffic demand in interactions along the whole session duration, are also incorporated into Grid services. This evolution has led to the so-called *Next-Generation Grid* (NGG). Considering the increase in number and performance of Internet-enabled handheld or mobile devices, any service provisioning concept must not ignore this development. Allowing Grid resources to be distributed across organizational boundaries and to be mobile brings about new application domains of Grid technology, e.g., in scenarios like e-health or disaster handling and crisis management [Mor06]. As a consequence thereof, a Grid architecture has to consider inter-domain issues, such as building trust relationships (or security in general), unreliability of services and resources, and problems related to mobility. This results in Mobile Collaborative Business Grids [Wes06].

Users consume services through the use of devices. Any of these three types of entities can be mobile: devices, users, and sessions. A session is defined as an in-

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[2] Within this context, an administrative authority has a central control of entire Grid resources. Traditionally, this is a single organization, but actually, nothing prohibits two or more organizations to let their computational resources be under the control of a single organization.

stantiation of a service over time. Device (terminal) mobility relates to the capability of the mobile device and the service infrastructure to maintain running (communication) sessions, even when points of attachment change. On the network layer, Mobile IP transforms the mobility problem into a routing problem, which it solves by adding new functionality to the network entity, in terms of an attendant and a home agent. User mobility refers to the capability of the infrastructure to correctly identify a user independent of the device she is using to access network and her personalized services. This capability is provided by a user-oriented security and authentication framework. Before access to network and services can be granted, a user has to register to his/her home organization. This authentication process aims at identifying the service consumer and at the same time also associates a user to a device in order to allow session management at the user level, including accounting of service consumption. Finally, session mobility enables the transfer of application sessions between any two devices without service interruption. A typical solution is provided by the *Session Initiation Protocol* (SIP). SIP can be initiated both by the user (terminal) and by the service infrastructure to redirect communications (e.g., image display) to a different device, retaining the association between users and sessions.

The EU Project Akogrimo [Wes06] advances the pervasiveness of Grid computing across Europe by uniting concepts and results gained in the systems *Beyond 3G* (B3G) and the Grid community. Fig. 6.2.2 depicts the NGG organizational model in which various resources and actors are brought into relation. A Virtual Organization (VO) is understood to be a temporary or permanent coalition of geographically dispersed individuals, groups, organizational units, or entire organizations that pool resources, capabilities, and information to achieve common objectives. A VO can provide services, including high-level resources, such as knowledge (e.g., user and device context information and state information of VO components), and it may comprise various types of service providers, such as Grid service providers, content providers, network service providers, and even other VOs. A *Mobile Dynamic Virtual Organization* (MDVO) is composed out of potentially mobile participants where contracts are dynamically established. The base VO comprises pools of potential resources, services, and providers, which are combined into an instantiation of the VO for one user or customer. This is termed an operational VO.

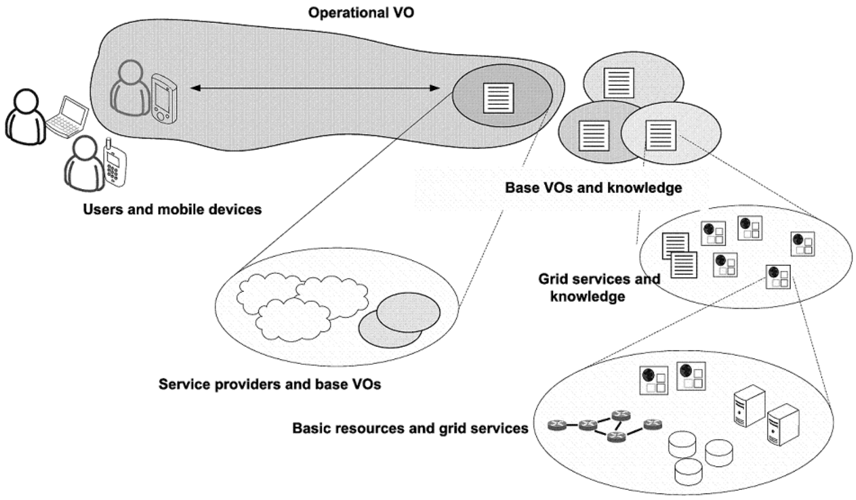

Fig. 6.2. Akogrimo Grid Organization Model.

Driven by business requirements furthermore, A4C functionality, i.e., user authentication, resource access authorization, multi-domain accounting, auditing of SLA compliance, and charging of resource consumption, is crucial for the commercial deployment of NGG technology for providers and users of *mobile Internet Grid services* (see Section 6.3.4). Thus, the Akogrimo NGG architecture offers A4C functionality within its network middleware components, which are also responsible for Quality-of-Service (QoS) and mobility support, context management, and service discovery. Besides network middleware, Akogrimo's architecture comprises components responsible for SLA negotiation and enforcement, establishment of VOs, creation of workflows, and task execution management [Has07].

6.2.6 High-altitude aerial platforms for providing broadband wireless access

Aerial platforms flying in the lower stratosphere at altitudes around 20 km and equipped with a communication payload can be used for the provision of broadband access to fixed or mobile users. Referred to as *High Altitude Platforms* (HAPs), they combine some of the best characteristics of terrestrial wireless and satellite communication systems, yet avoiding many of their drawbacks. Compared to terrestrial wireless technologies, HAPs require less communications infrastructure, they serve larger coverage areas from a single site, and the cell planning is more straightforward as they provide line-of-sight links. Compared to satellite systems HAPs will provide a quasi-stationary coverage area, low propagation delays, broadband capability using small sized antennas and terrestrial terminal equipment, and easy maintenance and upgrading of the payload. These characteristics make HAPs suitable also for the provision of broadcast and multicast services in addition to basic voice, video, and data communications and various advanced applications, such as telemedicine, videoconferencing, news gathering, localisation and navigation, or remote sensing. HAPs can be rapidly deployed and their flight path can be controlled in compliance with changing communication demands. Thus, they are well-suited also for temporary provision of basic or additional capacity requirements, providing network flexibility and reconfigurability. In this context typical applications of HAPs include short-term large-scale events and establishment of ad-hoc networks for disaster relief.

HAPs will provide broadband wireless access for single-user or group terminals located in the coverage area, serviced from ground stations operating as backhaul nodes. HAPs can operate as stand-alone platforms, or alternatively, as a network of platforms, if interconnected via the ground stations or via *inter-platform links* (IPLs) [TD(05)054]. In a HAP system, switching can be implemented on the ground or on board, depending on QoS requirements and on limitations regarding the weight and power consumption of the payload. While HAP system can be deployed as a stand-alone network, it will typically be connected to external networks via gateways providing suitable internetworking functionality.

In a stand-alone platform scenario communication is only enabled between terminals within the coverage area, or with terminals in other networks using a gateway located in the ground station. Thus, the stand-alone platform scenario is most suitable for temporary provision of basic or additional capacity for short-term events and for disaster relief missions.

In a multiple platform system HAPs can be interconnected via ground stations or via IPLs. In a network of platforms connected via ground stations the system coverage is no longer limited to that of a single platform, but it heavily depends on ground segment facilities. In this respect the interconnection of HAPs via IPLs provides extended system coverage with significantly reduced requirements for terrestrial infrastructure and up/down links, provides high flexibility of system coverage, and supports system operation independent of terrestrial network. In this scenario ground stations are used mainly as gateways to other networks. It is particularly attractive to bridge wider spans between ground stations and to reroute part of the traffic to less loaded ground stations and gateways. To support communication between adjacent platforms without any ground network elements each HAP communication payload includes a switching device and one or more IPL terminals. HAP system can also be integrated into other non-local terrestrial or satellite networks via satellite using platform-to-satellite links (PSL). Such system architecture is mainly targeted for the use in areas with deficient (rural and remote areas) or non-existing terrestrial infrastructure, hardly accessible even with mobile/portable ground stations. PSLs could also be used as a backup solution when the connection with the rest of the network via IPL or ground station is disabled due to a failure or extreme rain fading on up/down links. Integration of HAP and satellite systems is particularly interesting for some specific applications such as reliable multicast with the satellite providing a large coverage area and the HAP network catering for local retransmissions [Ber06].

Multiple platform system will typically be deployed by a single network operator to serve a target coverage area. In case of largely overlapped coverage areas such multiple HAP constellations can enhance the overall system capacity by exploiting highly directional fixed user antennas used to discriminate spatially between different HAPs [Gra02]. In mobile user environment multiple platforms can be used to increase the total link availability between the HAP and a user by exploiting the diversity gain [Cel06]. And by making use of load balancing between different HAPs and ground stations/gateways, multiple platform system can efficiently support traffic engineering [Moh07]

6.3 Business Models, AAA, Charging and Billing

Wireless service users today seek greater choice and customization in accessing telecommunications services. Their freedom of choice, however, has yet to transcend the constraints of the legacy subscriber era and acquire the attributes of modern consumer freedoms. Their desires for user controlled flexibility in service delivery, e.g., having it fully and automatically tailored to the users' needs, and for full portability freedom, e.g., the ability to move/migrate quickly to more competitive service providers offering better price/performance options or a wider selection of services, have yet to be addressed, not to mind be satisfied, through a formal overhaul of wireless communications from the business models to the network infrastructure. Key to creating new business models is the creation of new infrastructural forms of *Authentication, Authorization, and Accounting* (AAA), and charging and billing.

This chapter starts with a presentation of a new generic Consumer-centric Business Model (CBM) for future wireless communications proposed as a natural evolution and substitution of the legacy Subscriber-centric Business Model (SBM). The concept and core elements of this new CBM are set out in Section 6.3.1. Its claim is to enable realization of truly consumer-oriented, user-friendly and user-driven "always best connected and best served" (ABC&S) wireless communications environment, full zero-cost anytime-anywhere-anyhow portability for consumers, level playing field and relatively low entry-cost for new wireless access service providers, zero-cost international roaming, and the creation of new markets for such services as trusted *Third-Party AAA* (3P-AAA), wireless billboard advertisement of services, and third-party incoming caller connection services (see Section 6.2.4).

Supporting examples of the transition trend from SBM to CBM networking (Fig. 6.3) are presented in the rest of the chapter. Section 6.3.2 discusses the WiFi business models. Even though most of these are based on SBM, there are few examples (e.g., ticket-based WiFi access at hotels, airports) already moving in the direction towards CBM. Section 6.3.3 discusses a A4C mobile grid model for distributed service provisioning across multiple organizational domains based on a trust relationship and the use of ID tokens [TD(05)042]. Largely relying on SBM, this model is one step further towards CBM as all its new features (e.g., single sign-on, anonymity, multi-service accounting, and flexible charging) are inherent CBM features as well. Finally, Section 6.3.4 discusses models for supporting cooperation and accounting in multi-hop wireless networking. The credit systems discussed therein are the closest examples to creating a CBM-like environment. This is under the assumption that the centralized accounting credit clearance service is supplied by a 3P-AAA service provider as suggested in the CBM. The introduction of 3P-AAA in the proposed CASHnet system, in particular, will also eliminate the need for service stations and prepaid cards thus greatly facilitating the users.

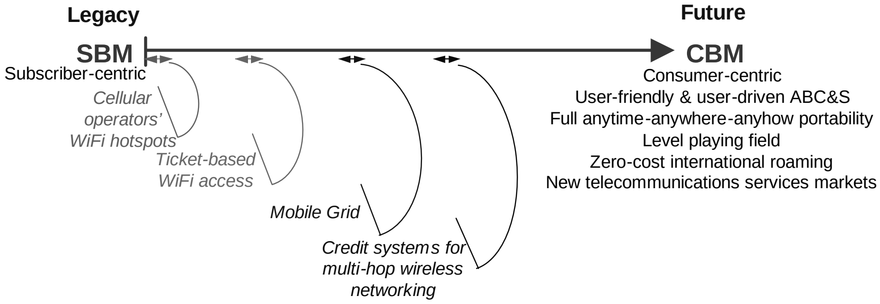

Fig. 6.3. SBM to CBM transition trend.

6.3.1 Consumer-centric Business Model for Future Wireless Communications

Strategic innovations through international standardization to enable the creation of a *Consumer-centric Business Model* (CBM) [O'Dr04], which will lead the evolution to a Ubiquitous Consumer Wireless World (UCWW) [O'Dr07].

The CBM for wireless communications is probably best appreciated by considering it in contrast with the legacy *Subscriber-centric Business Model* (SBM). At the core of the SBM is the network ownership of the local loop and the perceived need for this in order to provide the legacy teleservice of telephony, especially the *Incoming Call Connection* (ICC) service. In SBM the user has a well defined physical single point of attachment to the network. Whether mobile or fixed, it is mapped to a unique, globally significant, network-wide identity, i.e. a telephone number. The user has a contract with the home Access Network Provider (ANP) for a more or less long-term connection to this point of attachment, through the unique identity. Hence the user is naturally identified as a “subscriber” and the user’s unique identity is really jointly owned by the home ANP, at least for the duration of the contract.

The benefits and advantages of the SBM approach are apparent in today’s everyday experience of wireless networking, especially in relation to ICC services. However there are also many downsides. A subscriber of one ANP, for example, cannot easily access more attractive price/performance options for certain services of other ANPs. Changing ANPs–even with number-portability (whether legislated for or voluntary)–is problematic. A multiple SIM card solution (e.g., to bypass roaming charges or get local charges applied for local calls) is cumbersome and problematic especially in respect to the ability to receive incoming calls. Another example is roaming tariffs. They are perceived as being not cost-based and detailed information on them is usually not readily accessible, resulting in difficulties for economic management of wireless services when travelling.

Exploiting the difference in nature and ownership of the wireless local loop, as compared to the fixed local loop, is basis of the new business model, CBM. In wireless networks the local loop only comes into existence for the duration of a call. Thus it is a virtual local loop, using resources shared with others. Furthermore, the local loop medium used is not owned by the wireless ANP, even if aspects of it, e.g. frequency bands, are leased to ANPs. With this underlying technical foundation the “consumer” approach may be developed and the result–CBM-UCWW–is a paradigm shift from the present SBM wireless world. Some attractive benefits and core infrastructural elements of the CBM-UCWW are summarized below.

Consumer, CIM and 3P-AAA-SP: A significant and inherent CBM-UCWW benefit is the real possibility to satisfy the legitimate modern consumer expectation of being able to move back and forth readily among ANPs at any time for any and all services. Furthermore, such an attribute is a major contribution towards the realisation of the ‘always best connected and best served’ (ABC&S) capability for the consumers [O’Dr06]. Enabling this will mean the growth of much new business seeking to serve and support this ABC&S capability.

A key CBM enabler for this is *number ownership*. This inherently implies full anytime-anywhere-anyhow number-portability. The proposal discussed in this section includes a universal *CIM*[3] *card* or its software equivalent [O’Dr07], through which consumers would own their personal globally significant, network-independent number (IPv6 address). Through this, with whatever terminal the user chooses, s/he will behave as a consumer, i.e. will obtain and securely pay for services from any ANP or teleservice provider (TSP), anytime-anywhere (whether local or roaming). It is not unlike entering a shop and making purchases using a

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[3] *CIM* - Consumer Identity Module, analogous to SIM card thinking but based on CBM.

credit card. Implicit in such business transactions is the availability of network independent, autonomous, trusted *Third-Party Authentication, Authorization and Accounting Service Providers (3P-AAA-SPs)* [TD(05)041]. Not too unlike credit card companies, these 3P-AAA-SPs will be new business entities in the UCWW.

Local user and zero roaming charges: With CBM and through their CIM, consumers (wherever they are) would always appear as 'local users' to whatever networks they access. Implicit in being a 'local user' is that roaming charges disappear.

ANP marketplace: Creation of a more open, fair, level playing field in the ANP market is another significant benefit of CBM-UCWW. At present the market is dominated by a small number of large international-global access network providers. The present SBM technological infrastructure militates against 'start-up' ANPs (as distinct from virtual operators such as MVNOs), e.g., directed at niche or specialized markets. In a CBM environment, the up-front cost for new ANPs is not so prohibitive. For instance, they will not need to have in place, before commencing business, a large network and associated infrastructure (including roaming agreements) over a wide geographic base. Rather they can start small and grow their networks and consumer-customer base, just like new businesses in other market sectors. Hence, instead of being tied to make-or-break numbers of signed-up subscribers, profitability and survival may be linked to the number of consumer transactions they attract.

Integrated Heterogeneous Networking (IHN): Within UCWW IHN will be kick-started. This form of IHN is not driven by the networks. Rather it will be driven, managed, and controlled by consumers and TSPs at the network edge and will mainly be transparent to access networks. The CBM-UCWW will see a strong growth of wireless networking intelligence at the network edge - in the user terminals and TSP entities - leading to business opportunities for hardware and software manufacturers, and the likelihood that this form of IHN will become quite sophisticated in time.

Standardization: The global wireless communications business is vitally dependent on standardization for realization. The creative CBM-UCWW proposal requires the underpinning of some strategic international standardization. This will be pivotal for the support of key new entities and functionalities, such as 3P-AAA-SPs, CIM, wireless billboard channels and their providers [TD(06)054], and non-ANP ICC-SPs (see Section 6.2.4). Once these are in place the UCWW will begin to take shape and grow along an evolutionary path (as happened with, and in parallel with, the existing wireless world founded on the SBM) yielding social, economic and business benefits for users, access network providers, equipment manufacturers and software developers, the full range of teleservice providers and new business entities.

6.3.2 Business models for WiFi public networks

During the last five years IEEE 802.11 or WiFi (Wireless Fidelity) technology has been widely deployed for private use as a residential and company local area wireless network technology, as well as one of the access technologies for the public wireless data networks. The widespread and successful support of WiFi in portable and handheld devices, combined with the simplicity and low costs of network deployment, has encouraged traditional operators and alternative actors, such as wireless communities, local administrations and entrant *Wireless Internet Service Providers* (WISPs), to build WiFi public access networks and explore new commercialization models and value chains. Many of these new business models are not based on typical vertical business models applied in the traditional wireless service delivery value chain, controlled by the cellular operators, but involve co-operation among new alternative actors in the telecommunications arena.

As shown in [TD(06)019], three main types of WiFi business models can be considered: the commercial hotspot business model applied by fixed and cellular traditional and entrant operators; the wireless commons models applied by citizen and grassroots communities; and the neutral models used mainly by local administrations in the deployment of WiFi city-wide public networks.

The hotspot business model is based on deploying a group of access points connected to a common service infrastructure setting, applying various billing models or even free of charge services. The initial promoters of these initiatives were mainly small companies specialized in the deployment and operation of WiFi networks in hotel lounges, cafeterias, hub stations, airports, etc. Even though the success of these companies has been modest, the proliferation of terminal equipment integrated with WiFi communication capacities, as well as the excellent future forecasts predicted by strategy consultants for this market, have raised the interest of fixed and cellular operators to become involved in the hotspots business, accounting nowadays for the larger hotspots networks in most of the European countries. Also, many retail business', such as coffee shops, are providing free WiFi services, in order to attract more customers. Hotspot aggregators, such as Boingo, provide service in multiple sites worldwide, through roaming agreements with local WISPs.

The actual trends for the hotspot model points to a concentration of the market around several big players: fixed and cellular operators such as Telefonica or T-Mobile that are integrating the hotspots service into their regular telecommunication offer, and the aggregators that are merging in order to take control of a larger hotspot base, such as Boingo.

As discussed in Section 6.2.2, the future interaction between 3G and WiFi hotspots is an important issue to define the future role of WiFi hotspots in the 4G arena, and the possibilities of WiFi technology to complement, compete or converge with the existing 3G and 2G networks that support the core business of the cellular operators [Leh03].

Wireless communities have received a lot of attention from the mass media and part of the research community, as the paradigm of a cooperative network deployment model. The *wireless commons* model applied by these communities does not target to achieve economical benefits, but to openly share the network infrastructure among the actors deploying the network and the final users. Each of the participants in this model contributes to a small part of the network, generally one or several wireless access points. Although the main service provided is Internet access, the above networks also share content generated by users, and voice over IP is increasingly being used, utilizing free/open source software such as Asterisk[4].

The empirical evidence [San04b] shows that most of these grassroots initiatives are small and weak and cannot articulate a real alternative to the commercial models. Nevertheless, some have been successful by focusing on the real needs of the citizens in two contexts: initiatives extending the broadband coverage in rural areas, as the case for Guifi accounting for 4.000 already deployed nodes in a rural area in Catalonia (Spain), and initiatives supporting retail commerce and citizen communities to deploy free host-pots, as the case for Austin in Texas (USA).

The weaknesses for the wireless communities model are centred on legal aspects, difficulties in involving participants not interested in the technology per se, and lack of complete QoS support over heterogeneous networks. Despite these obstacles, there is an important growth of grassroots community networks, and interesting hybrid business models, such as FON that combines the hotspot commercial model with the wireless common communities model.

The third type of organisational model is the one used by many local administrations in order to promote municipal WiFi networks. In the last years, many municipalities, mainly in the USA but also nowadays in Europe, are entering the public networks market basing their deployment in hotspots or citywide wireless access networks. The municipalities see WiFi networks as a tool for improving the service offered to the citizens, reducing telecommunication costs, increasing the competition in the network access market, supporting advanced telecommunication services that can attract information intensive companies and professionals, and helping to reduce the digital gap [Inf07].

The neutral model applied by many municipalities involves contracting to a specialized company the deployment and operation of an area or citywide WiFi network [Inf06]. The company in charge of the network operation sells wholesale services to retail ISPs, and the local administration acts as an anchor tenant using the WiFi network for internal municipal services. The commercialization models range from publicity-based free service for citizens, to flat rate monthly subscription.

The evolution of municipal models depends on several factors, which include legal aspects on the law on competition, which constringe the deployment and introduction of competitive services in cases where there is competition between the

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[4] See Asterisk, the opensource PBX. http://www.asterisk.org

private and the public initiative, and the economical viability of municipal initiatives, which will allow or inhibit the medium and long-term survival of public-promoted WiFi services. Although it is still too early to asses this point, municipalities have shown an increasing interest and there are many municipal-owned and mixed public/private initiatives ongoing in Europe, the USA and Asian countries as Korea and Japan.

6.3.3 Charging and accounting for mobile grid services

A business-oriented Grid infrastructure, built across multiple organizational domains on top of which different providers virtualize their services, requires accounting and charging mechanisms necessary for providers to charge for the consumption of their services.

In the Akogrimo [WJE06] project an approach to design and implement a commercial Grid solution for service providers and telecom operators in support of mobile users has been undertaken. It provides relevant mechanisms to deploy Grid applications in a mobile environment. I what follows, accounting and charging mechanisms for mobile Grid services in a multi-provider setting are addressed here.

6.3.3.1 Accounting and Charging in IP and Grid Networks

Over the last few years, multiple research efforts have been undertaken on accounting, charging, and pricing models for telecommunication operators and ISPs (Internet Service Provider). For IP networks the generic Authentication, Authorization, and Accounting (AAA) architecture [Laa00] determines the basis for accounting of IP-based services, where the RADIUS protocol is widely used to transfer accounting records. The Diameter protocol has been developed by the IETF (Internet Engineering Task Force) as the next generation AAA protocol, overcoming many limitations of RADIUS, such as lack of support for mobility and limited flexibility.

Accounting of Grid services has been addressed recently in several research projects. Most existing solutions for Grid accounting (see [Pir03], [Bar03], or [San04]) implement proprietary accounting and charging mechanisms. Additionally, any interconnection of accounting and charging functions with existing systems is not part of those solutions either.

6.3.3.2 A4C for Mobile Grids

Accounting and charging mechanisms have to capture specific characteristics of each entity involved so that seamless interoperability between different business partners is assured, not only for service provisioning, but also for generating and sharing revenue. Akogrimo's A4C (Authentication, Authorization, Accounting, Auditing and Charging) infrastructure developed in [TD(06)042], [Mor06], [Has07], integrates standardized accounting mechanisms defined by IETF into a Grid environment. Figure 6.4 shows how A4C components are deployed within a Grid environment spanning across several domains.

The A4C server is the central component of the architecture. At least one A4C server needs to be present in every organizational domain. Its main tasks include the authentication of users, access control to services, service usage accounting, and charging. Additional tasks performed by the A4C server include the auditing of service consumption for QoS compliance and storing of user and service specific profiles. Service components communicate using the Diameter protocol with an A4C server via A4C clients embedded in those components. Moreover, A4C servers also manage inter-domain related tasks such as authentication and authorization of roaming users, or accounting and charging for compound service sessions spanning multiple domains. Most importantly, the A4C server keeps all internal data intact and consistent. For achieving this, the architecture uses a logically centralized A4C server. The central approach has to be seen only in the context of the architecture design. The physical deployment of the A4C server might include several physical nodes acting as A4C servers, i.e. for load-balancing purposes or for distributing A4C tasks to specialized nodes.

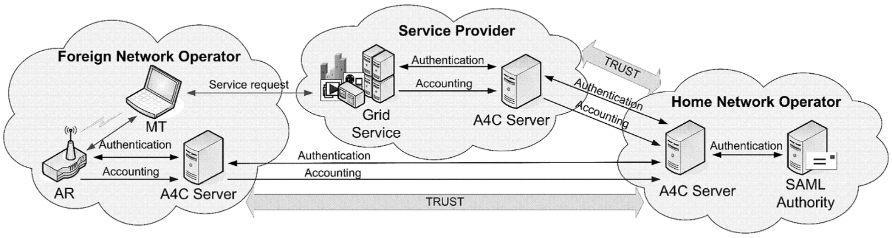


Fig. 6.4. A4C Infrastructure.

For two A4C servers in different domains to communicate, a trust relationship must exist between the domains. The inter-domain communication is also based on the Diameter protocol. The A4C client is the counterpart to the A4C server on the client side, enabling network or Grid components access to A4C services.

Another component of the A4C infrastructure is the SAML (Security Assertion Markup Language) authority component. SAML is used to send security information in the form of authentication and attribute assertions to mobile Grid components. The SAML authority has been designed as an internal subcomponent of the A4C server. It supplies identity tokens (IDTokens) and SAML assertions to the

A4C server. The A4C server contacts the SAML authority, when it requires to generate IDTokens and to verify such tokens presented by different components.

Support for *Single Sign-On* (SSO) and anonymity is achieved by using IDTokens. An IDToken is a piece of information that can be linked to a previous authentication event without providing user credentials to the component that wants to check the authenticity of a user. IDTokens are generated after an initial successful authentication and may be used later for requesting services. The IDToken does not reveal a user's real identity, but only an entity that can prove that the user is authenticated and provide a user identity for the token.

6.3.3.3 A4C Session Model

Accounting and charging of composed services requires that service composition is visible also in the A4C components. This can be achieved by creating A4C sessions. An A4C session can be an authentication, authorization, or accounting session for a running service session. Whenever services are automatically instantiated and aggregated by service composition entities, A4C session hierarchies are created. Session hierarchies keep track of how multiple services interact in order to assure the delivery of a more complex application. A4C components maintain session hierarchies by using two techniques: unique identification of each A4C session and tracking of each session's parent. The unique identifier is globally unique for each session, so that service hierarchies across multiple domains can be formed. Tracking of parent sessions assures that every service being executed by a service provider can be tracked to a service session requested by a user, and charged accordingly.

6.3.3.4 Conclusions

The A4C architecture provides a set of key functions for commercial service provisioning, such as authentication and authorization with single sign-on support, multi-service accounting and auditing of service consumption, and flexible charging. Based on the A4C session model the architecture is able to correlate accounting and charging activities in case of distributed service provisioning and across several organizational domains. The A4C architecture presented was successfully evaluated in a mobile Grid scenario.

Further work will focus on the integration of a charging settlement entity, the integration with existing Grid accounting systems, and an investigation of detailed Grid accounting and charging policies.

6.3.4 Cooperation and accounting for multi-hop wireless networks

Cooperation is necessary for packet forwarding in wireless multi-hop networks. If all nodes would transmit their own packets only, they could only communicate with direct neighbors, but not with other nodes. Cooperation in multi-hop networks can be either enforced or encouraged. With cooperation by enforcement, uncooperative nodes get punished so severely, that they do not have another choice than to cooperate. However, the underlying assumption that all nodes are always able to cooperate ignores situations such as low battery or high congestion, where nodes may be unable to cooperate, even if they want. Nodes must be monitored and evaluated by their neighbors in order to determine, whether nodes are cooperative. This requires typically overhearing functions, e.g., to detect whether nodes forward received packets. Selfish nodes that do not forward traffic for others might be excluded from the forwarding path or excluded from the network [Buc05]. Most proposed mechanisms assume source routing. Nodes can be rated according to their forwarding behavior and paths with the highest node rating are selected [Mar00]. This approach does not have effects on well or misbehaving nodes. CONFIDANT [Buc03] observes one-hop neighbors for building reputations. When a node's rating exceeds a certain threshold, all paths containing the accused node are deleted from the route cache and an alert message is sent to interested nodes, which evaluate the credibility of the alert using a trust manager. Misbehaving nodes may be isolated: They are neither used for forwarding nor are their packets forwarded. Reputation systems [Mol02] may distribute positive ratings about nodes and store negative ratings only locally. A misbehaving node can repent by providing service to other nodes that did not rate it negatively yet. Punishment can be performed by reducing the throughput of accused nodes. This can be achieved by temporarily valid tokens that must be renewed for node participation in the network [Yan02]. The token is signed by a private key shared among several other nodes. A new token can only be generated by a certain number of other nodes, which only support renewal in case of no detected misbehavior. Reputation-based systems cause rather high computation and communication overhead due to the propagation of reports. Trust and reputation are rather difficult to determine. Misbehavior and errors are difficult to distinguish.

Cooperation by encouragement is based on the assumption that nodes may be reluctant to cooperate. Cooperation can be encouraged or motivated by compensations and incentives that are attractive enough to overcome the user's reluctance. With the Nuglet mechanism [But03] the transmission of a packet costs a certain amount of nuglets depending on the number of nodes along the path. Forwarding nodes earn a nuglet per forwarded packet. Nodes maintain pending nuglet counters for each neighbor node, with which they pre-established symmetric-key sessions. When a node receives a forwarded packet, it increases the pending nuglet counter of the forwarding neighbor node. Pending nuglets are distributed by a synchronization protocol causing additional network overhead. The approach presented in

[Jak03] is based on rewards, similar to a lottery and on payment tokens as proposed by [Mic02]. The originator node adds a payment token to its self-generated packet. Forwarding nodes apply a function to this token to see whether it is a winning ticket and request the reward from a base station, which forwards a fraction of the requests to the accounting center that rewards claims statistically. Forwarders get rewarded, if no cheating behavior can be detected, which might be challenging to determine. Originators of packets are charged on a usage-based fee. Sprite [Zho03] introduces a virtual currency, so-called credits, and a centralized account management, called credit clearance service. When a node transmits a packet, it loses credits to the network and when it forwards packets, it gains credits. For each transmission, the credit clearance service balances the accounts of all involved nodes: The originator is charged and the forwarders get rewarded. Nodes can buy additional credits from the credit clearance service. To correctly balance the accounts, the credit clearance service must keep track of each transmission in the network. Nodes periodically transmit the collected receipts to the credit clearance service, which determines the charges and rewards based on the reported receipts. The concept presented in [Sal05] describes a payment scheme for multi-hop cellular networks with low mobility. Accounting is performed by the operator, which maintains the accounts of all nodes. The originator node creates a message authentication code over the packet and encrypts the packet using its session key. Each intermediate node towards the base station stores a receipt of each received packet and encrypts the packet with the own session key. The base station retrieves all session keys and verifies the message authentication code. If the verification is successful, the originator's account is reduced and the intermediate nodes get rewarded. The packet is then transmitted to the base station of the destination node, which encrypts the packet with the intermediate nodes' session keys. The destination acknowledges the reception of the packet to the base station, which finally distributes the rewards. A deposit on the account of a destination is charged and only refunded if an acknowledgement is received by the base station.

The CASHnet charging and rewarding mechanism [Wey05a, Wey05b, TD(05)027, is based on so-called traffic and helper credits. Prior to the transmission of a self-generated packet, the origin's traffic credit account is charged and the packet is digitally signed. Like Nuglet, CASHnet relies on tamper-resistant hardware (smart cards in mobile devices) and cryptographic means. The charged amount is either related to the current distance in hop counts to the gateway or a globally fixed price. Upon arrival of a packet at its destination, the destination's traffic credit account is also charged. Each intermediate or destination node receiving a packet rewards the previous node, if it was not the origin or a gateway by sending a digitally signed acknowledgment. This is done immediately after reception or after receiving several forwarded packets. Receiving an acknowledgement increases the node's helper credits account. Traffic credits can be bought for real money or traded for helper credits at service stations, which are similar to terminals for loading prepaid cards and have a secure, low-bandwidth connection to the provider for authentication and payment operations.

The lack of service stations in Nuglet enforces cooperation, since nodes are not able to generate traffic without cooperation. However, nodes might not get enough packets to forward from their neighbors, so that they will not earn enough nuglets to transmit their own packets. CASHnet tries to reduce this risk by service stations. Moreover, in order to allow greater flexibility and independence from service stations, CASHnet has been extended by resale of traffic credits against helper credits. A node can act as a reseller by offering its traffic credits for helper credits to a buyer node. A buyer node lacking traffic credits can ask its one-hop neighbors for the resale conditions. Resale among nodes implies the secure exchange of virtual currency over the wireless network. Another difference between Nuglet and CASHnet is on the used security mechanisms. Symmetric key sessions reduce the computational overhead in Nuglet, but have strong limitations concerning mobility of nodes. Therefore, CASHnet uses public key cryptography, although this is computationally more expensive. The feasibility of the approach has been proven in [Wey06]. Both Nuglet and CASHnet have been evaluated using ns-2 simulations, which showed that a self-perpetuating cycle of virtual money is difficult to achieve. The amount of virtual money decreases over time for Nuglet, which makes the long-term operation questionable. CASHnet performs better than Nuglet in scenarios with high network load independent of the number of service stations. In scenarios with low network load, CASHnet requires 2-5 service stations to perform better than Nuglet.

6.4 Optimization based on User/Application Requirements and Cost/Revenues Aspects

This section discusses the optimization of mobile and wireless networks, based on user/application requirements and cost/revenue aspects. The optimization of Enhanced UMTS networks from a cost/revenue point of view is first investigated. This requires the identification of the system costs and the obtainable revenue. Next, the section investigates the optimization of wireless LANs based on user/application requirements, expressed in the form of utility functions.

6.4.1 Cost/revenue analysis of Enhanced UMTS services

In order to optimise Enhanced UMTS networks from the cost/revenue point of view, one makes use of results for network optimisation by using the models described in Section 3.4.2 [TD(05)051, Cab06a]. The system cost contains a fixed term, C_{fi}, and a term proportional to the number of BSs, C_{fb}. So, the overall cost of the network per unit length or area, *ula*, per year is [Vel03, Vel00, Gav95]

$$C_{0\,[\text{€}/ula]} = C_{fi[\text{€}/ula]} + C_{fb\,[\text{€}]} \cdot N_{c/ula}., \tag{6.1}$$

where $N_{c/ula}$ is the number of cells per unit length or area. C_0 and C_{fi} are also given per unit length or area, *ula*. The estimation of the variation of system capacity, obtained for a given grade of service obtained from network optimisation, is an input for the revenues. The revenue per cell per year, $(R_v)_{cell}$, can be obtained as a function of the throughput per BS, $thr_{\text{BS [kb/s]}}$, and the revenue of a channel with a data rate $R_{b[\text{kb/s}]}$, $R_{Rb[\text{€/min}]}$, is obtained by

$$(R_v)_{cell\,[\text{€}]} = \frac{thr_{BS\,[kb/s]} \cdot T_{bh} \cdot R_{R_b[\text{€}\,/\,\text{min}]}}{R_{b[kb\,/\,s]}}, \tag{6.2}$$

where T_{bh} is the equivalent duration of busy hours per day.

The revenue per unit length or area per year, $R_{v[\text{€}/ula]}$, is obtained by multiplying the revenue per cell by the number of cells per unit length or area

$$R_{v[\text{€}/ula]} = N_{c/ula} \cdot (R_v)_{cell\,[\text{€}]}. \tag{6.3}$$

A project duration of 5 years and a null discount rate were assumed. Costs and revenues are taken on an annual basis, and six busy hours per day, 240 busy days per year [Vel03] were assumed. The revenue/price of a 144 kb/s "channel" per minute is $R_{144[\text{€/min}]}$ and corresponds to the price of one MB of information, approximately). Hence, the revenue per cell can be obtained as

$$(\mathrm{R_v})_{\text{cell}[\text{€}]} = \frac{thr_{BS[\text{kb/s}]} \cdot 60 \cdot 6 \cdot 240 \cdot R_{144[\text{€/min}]}}{144_{[\text{kb/s}]}} \tag{6.4}$$

In the future, with the equipment normalization and mass production, the equipment prices will get lower, making Enhanced UMTS affordable. Table 6.4 presents the hypothesis for the 144 kb/s "channel" in different scenarios.

	Offices	BCC	Urban
	0.02	0.10	0.01
$\mathrm{R}_{144[\text{€/min}]}$	0.005	0.05	0.05
		0.025	0.10

Table 6.4. Hypothesis for $R_{144[\text{€/min}]}$ for offices, urban, and BCC scenarios.

Two hypotheses were assumed for costs A) and B), Table 6.5, [Joh04]. Costs are different for several scenarios, since the office scenario uses pico-cells, the BCC one uses micro-cells, and the urban uses macro-cells. $C_{fb\,[\text{€}]}$ is computed by

$$C_{fb[€]} = \frac{C_{BS} + C_{Inst}}{N_{year}} + C_{M\&O} \tag{6.5}$$

Parameters	Pico-cell		Micro-cell		Macro-cell	
	A	B	A	B	A	B
Initial Costs:						
BS price, C_{BS} [€]	5000	2500	8000	3200	50000	25000
Installation, C_{Inst} [€]	3000	250	2490	208	30000	30000
License fees, C_{fi}[€/uca]	1000	1000	1590	1590	1590	1590
Annual Cost:						
Operation and maintenance, $C_{M\&O}$	1000	250	750	188	3000	750

Table 6.5. Hypothesis for costs.

The profit, P_{ft}, an important result to optimise the network, is given by the difference between the revenues and the costs, in €/ula, while the profit in percentage is given by the net revenue normalised by the cost, i.e.,

$$P_{ft[\%]} = \frac{R_{v[€/km]} - C_{0[€/km]}}{C_{0[€/km]}} \cdot 100[\%] \tag{6.6}$$

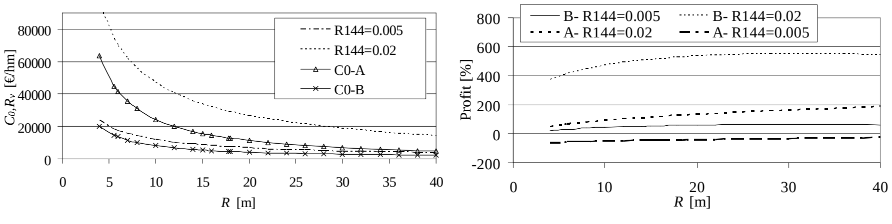
The offices scenario has a linear geometry with two levels, i.e., two rows of offices (located side by side) along a central corridor. In this geometry, with an area $w \times l$, where w is the width and l is the length, and BSs are alternately located inside offices at each side of the corridor. The number of cells per hectometre is given by

$$N_{c/hm} = \frac{l_{[hm]}}{R_{[hm]}} - 1 \tag{6.7}$$

where $l_{[hm]}=1$. Figure 6.6 (a) presents results for the overall cost per unit length per year, $C_{0[€/hm]}$, and the revenue per unit length per year, $R_{v[€/hm]}$, for the cases $R_{144[€/min]}$= 0.005and 0.02 in the offices scenario. By comparing revenues in hypothesis A (for costs), one can conclude that for the lowest values of revenues, $R_{144[€/min]}$=0.005, the costs are higher than revenues, while for $R_{144[€/min]}$=0.02 revenues clearly overcome costs.

Figure 6.6 (b) presents the profit in percentage per unit length. By analysing these curves, optimum/maximum values, around 30-32m, are only found for hypothesis B, the case of lower costs. By varying $R_{144[€/min]}$ from 0.005 to 0.02 there is no significant variation on the optimum coverage distance but the profit increases about eight times, from 63% to 552%. By using hypothesis A, i.e., higher costs, no optimum coverage distance was found in the range of the simulations. Furthermore, profit is negative when $R_{144[€/\text{min}]}= 0.005$.

Although in hypothesis A the reduction of cells size is not profitable, even if there is a need to support a given system capacity, results from case B shows that a higher number of pico-cell can be installed in the future, when costs of deploying and maintaining the network will decrease, allowing the support of higher capacity.



(a) (b)

Fig. 6.5. (a) Costs and revenues per unit length as a function of *R*, and (b) profit per unit length as a function of *R*.

In the urban scenario, the cellular geometry at two dimensions is arbitrary and has to cover an area of 4 km^2. The number of BS per km^2 can be obtained by using

$$N_{c/\,km^2} = \frac{1}{-0.0168 + 2.7729 \cdot 10^{-5} \cdot R^{1.3674}} \tag{6.8}$$

In [TD(06)045, Cab06b] costs/revenues per km^2 were analysed as a function of *R*, for the urban scenario, when three wideband amplifiers are used. The case $R_{144[€/\text{min}]}=0.01$ is the only one with negative profit. Figure 6.7 presents the dependence of the profit in percentage on the cell radius for three amplifiers per BS in the urban scenario. In this case, it can be observed that the curves have a decreasing behaviour. The most profitable radius will be 257m (the lowest simulated one). By varying the price from $R_{144[€/\text{min}]}=0.01$ to $R_{144[€/\text{min}]}=0.05$, or to $R_{144[€/\text{min}]}=0.10$, a variation in the profit from -18% up to 308%, or to 716% is obtained (in hypothesis A).

Results for the most profitable cell radius are obtained via an optimisation procedure based in economic aspects. For offices scenario, a higher number of pico cells (with a smaller radius, around 30-32 m) can be installed in the future, when costs of deploying and maintaining the network decreases, allowing for supporting higher system capacity, and reducing prices.

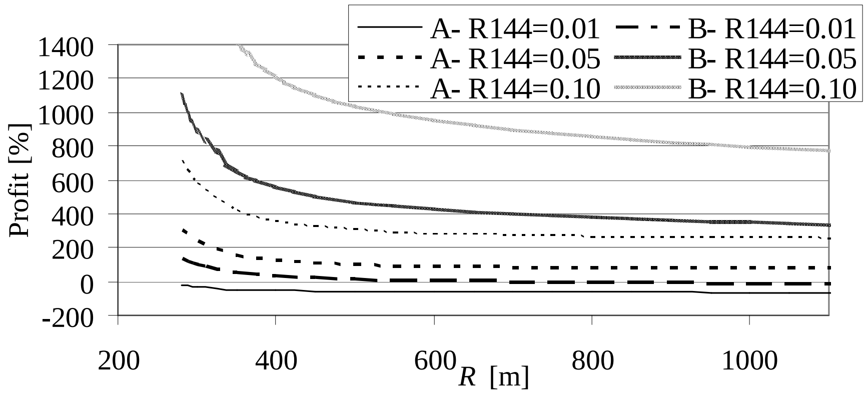


Fig. 6.6. Profit per km^2 as a function of R.

For the urban scenario, the profit in percentage is a decreasing function with R. The communications prices vary from 0.016 to 0.07 €/min, for R=250 and 1075m, respectively.

Results for costs, revenues, and profit in the BCC scenario are presented in [TD(07)047], [Vel07]. Although detailed results are not presented here, by considering the hypothesis for the price per minute of Table 6.4, the hypothesis for costs shown in Table 6.5 and $C_{fi[€/km]}$ =1590/5= 318€/km, the revenues the costs, and the profit in percentage are obtained for the several hypothesis.

Regarding the profit in percentage, optimum values are obtained for R~565m and R~520m for hypothesis A and B, respectively. For $R_{144[€/min]}$ = 0.10 min the profit takes values near 576% for hypothesis A and of 1688 for hypothesis B.

6.4.2 Utility-based optimization of wireless networks

This subsection investigates the problem of efficient resource control for elastic traffic in IEEE 802.11e's Enhanced Distributed Channel Access (EDCA) mechanism. The approach followed considers an economic modelling framework based on congestion pricing that captures how various factors, such as the probability of attempting to transmit a frame, the influence of the basic CSMA/CA or the RTS/CTS procedure and the physical layer transmission rate, contribute to congestion. The application of such a framework has also been applied to Wideband CDMA Networks [TD(04)004]. Applications of the above framework include class-based throughput differentiation, explicit congestion notification (ECN) marking based on the amount of resource usage and the level of congestion in the wireless channel, and modelling the performance of TCP congestion control over EDCA.

Several analytical studies have approximated the congestion avoidance procedure of 802.11 with a p-persistent model [Cal00], [Qia02]. In a p-persistent model, the probability p that a station tries to transmit in a time slot is independent of previous transmission attempts. The p-persistent model closely approximates the throughput of the actual congestion avoidance procedure when the average backoff is the same [Cal00]; additionally, the saturation throughput has a small dependence on the exact backoff distribution [Kum05].

6.4.2.1 Throughput model for IEEE 802.11e

If $E[CW]$ is the average contention window, then the approximate p-persistent model has transmission probability $p = \frac{2}{E[CW]+1}$ [Cal00]. If the probability of a frame being involved in more than one collision is very small, then $E[CW] \approx CW_{\min}$ [Qia02]. In IEEE 802.11e, different wireless stations can have a different minimum contention window value, hence the corresponding transmission probability of station *i* is

$$p_i = \frac{2}{CW_{\min,\, i} + 1}. \tag{6.9}$$

802.11's MAC layer operation can be viewed in time as involving three different types of time intervals: a successful transmission interval, a collision interval, and an idle interval. Denote the length of the first two interval types as T^{suc}, T^{col}, and assume they are normalized to the duration of the idle interval. The duration of these time intervals depends on the physical layer encoding and the MAC layer operation (e.g., use of basic CSMA/CA or RTS/CTS procedure).

The average throughput for station *i,* considering a renewal assumption, can be expressed as the ratio of the average amount of data transmitted by that station in one time interval, over the average time interval $x_i = \frac{E[X_i]}{E[T]}$ [Bia00], [CCG00], [QiSh02]. If the individual transmission probabilities p_i and the aggregate transmission probability are very small, then the average throughput for station *i* is well approximated by [Sir06]

$$x_i = \frac{p_i (1 - P_{-i}) L}{\sum_k p_k (1 - P_{-k}) T^{suc} + \sum_k p_k P_{-k} T^{col} + 1 - P}. \tag{6.10}$$

where L is the frame length, which for simplicity we assume to be the same for all stations, $P = \sum_j p_j$ is the aggregate transmission probability, and $P_{-k} = \sum_{j \neq k} p_j$.

In 802.11b with RTS/CTS, the transmission rate does not affect the collision interval, since collisions involve RTS frames which are always transmitted at the basic rate (1 or 2 Mbps), based on which the above equation for the throughput can be appropriately modified [Sir06].

If N is the set of users in the network, then the global problem of maximizing the aggregate utility (social welfare) is

$$\text{maximize } \sum_i U_i(x_i), \text{ over } \{p_i \geq 0, i \in N\}. \tag{6.11}$$

If $U_i(\cdot)$ is differentiable and strictly concave, then the necessary conditions for the maximization in (6.11) are

$$\frac{\partial \sum_i U_i(x_i)}{\partial p_i} = \frac{\partial U_i(x_i)}{\partial p_i} + \sum_{j \neq i} \frac{\partial U_j(x_j)}{\partial p_i} = 0, \tag{6.12}$$

for $i \in N$. Note that above conditions hold when the optimum is achieved for transmission probabilities in the interior of [0,1], which as our experiments show is indeed the case for utility functions we have considered and parameter values that correspond to IEEE 802.11.

In the case where all wireless stations have the same transmission rate, a station's throughput is given by (6.10). Substituting this equation in (6.12) we find that the necessary conditions for the global optimum are

$$\frac{\partial \sum_i U_i(x_i)}{\partial p_i} = L \frac{(1-P)^2 T^{suc} + P(2-P) T^{col}}{E[T]^2} \sum_j U'_j p_j, \tag{6.13}$$

for $i \in N$, where $P = \sum_j p_j$ and $U'_j = \frac{dU_{j(x)}}{dx}$; if $p_i << P$, which will hold when there is a large number of stations, we have $E[T] \approx P(1-P)T^{suc} + P^2 T^{col} + 1 - P$.

6.4.2.2 Applications

Next applications of the model presented in the previous section are discussed. A more detailed discussion of the various applications is contained in [Sir06], [TD07(07)007].

- Class-based proportional sharing: For proportionally fair sharing, the utility for user *i* is $U_i(x_i)=w_i \log x_i$ [Kel97]. Substituting this utility in (6.13), one can determine the optimum transmission probabilities, hence the optimal values of the minimum contention window for different classes. This computation can be performed at the access points, which periodically communicates the minimum contention window values to the wireless stations. Such a procedure is compatible with the approach identified in the IEEE 802.11e standard supplement.
- ECN marking: The model presented in the previous paragraph can be used to determine the optimum feedback that needs to be sent to each user, so that the user acting rationally to optimize his net benefit selects the optimum transmission probability, hence the optimum minimum contention window, that achieve the global optimum. In this way, the global optimum is achieved in a distributed manner.
- TCP over EDCA with ECN marking: TCP congestion control can be viewed as having the following implicit utility $U_{TCP}(x)=-\frac{2}{RTT^2 x}$ [Kel00], where *RTT* is the round trip time. Substituting this utility in the expressions presented in the previous section enables estimation of the optimum minimum contention window in the case of flows that have the same macroscopic behaviour as TCP.

6.4.2.3 Conclusion

The success of mobile and wireless services, in addition to technological and performance issues, depends heavily of service models and deployment scenarios. One important factor of value added service provisioning is contract formation, which in addition to adhering to legal requirements in different territories, must be automated in order to be efficient and facilitate conflict settlements.

WiFi, enhanced UMTS, and mobile grid services will influence future mobile and wireless networks. Their exact role will depend on market characteristics and the evolution and success of consumer and subscriber business models. Another requirement for successful commercialization of value-added mobile and wireless services is the efficient support of Authentication, Authorization, Accounting, Auditing, and Charging procedures, which need to adhere to relevant standards while considering the particular characteristics of the underlying technologies.

Finally, the success of value-added mobile and wireless services will also depend on the efficient utilization of scarce wireless resources, which should consider cost/revenue aspects, in addition to user and application requirements.

6.5 References

[Ber06] M. Berioli, G. Giambene, I. Alocci, M. Mohorcic, E. Ferro, F. Perez Fontan, F.-N. Pavlidou, Hybrid HAP-satellite architecture for reliable multicast transmissions, 23rd AIAA International Communications Satellite Systems Conference (ICSSC-2005), 2005.

[Bar03] Barmouta, R. Buyya, GridBank: A Grid Accounting Services Architecture (GASA) for Distributed Systems Sharing and Integration, International Parallel and Distributed Processing Symposium (IPDPS), 2003.

[Bia00] G. Bianchi, Performance analysis of the IEEE 802.11 distributed coordination function, IEEE Journal on Selected Areas in Communications, Vol. 18, No. 3, pp. 535-547, March 2000.

[Buc03] S. Buchegger, J.-Y. Le Boudec, The effect of rumor spreading in reputation systems for mobile ad hoc networks, 1st Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt), 2003.

[Buc05] S. Buchegger, J.-Y. Le Boudec, Self-policing mobile ad hoc networks by reputation systems, IEEE Communications Magazine, pp. 101-107, July 2005.

[But03] L. Buttyán, J.-P. Hubaux, Stimulating cooperation in self-organizing mobile ad-hoc networks, ACM Mobile Networks and Applications, pp. 579-592, October 2003.

[Cel06] T. Celcer, G. Kandus, T. Javornik, M. Mohorcic, S. Plevel, Evaluation of diversity gain and system capacity increase in a multiple HAP system, International Workshop on Satellite and Space Communications (IWSSC), 2006.

[Cab06a] Orlando Cabral, F.J. Velez, G. Hadjipollas, M. Stylianou, J. Antoniou, V. Vassiliou, A. Pitsillides, Enhanced UMTS cellular planning for multiple traffic classes in offices scenarios, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), 2006.

[Cab06b] O. Cabral, F. J. Velez, C. Franco, R. Rei, Urban cellular planning optimisation of multi-service enhanced UMTS based in economic issues, International Conference on Wired/Wireless Internet Communications (WWIC), 2006.

[Cam04] G. Camarillo, M. A. García-Martín. The 3G IP Multimedia Subsystem (IMS): Merging the Internet and the Cellular Worlds. Ed. John Wiley & Sons, 2004.

[Cal00] F. Cali, M. Conti, E. Gregori, Dynamic tuning of the IEEE 802.11 protocol to achieve a theoretical throughput limit, IEEE/ACM Transactions on Networking, Vol. 8, No. 6, pp. 785-799, 2000.

[ETSI98] ETSI, Technical Report Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.2.0), ETSI TR 101 112 V3.2.0, Sophie Antipolis, France, April 1998.

[Fer05] J. Ferreira, F. J. Velez, Enhanced UMTS services and applications Characterisation, Telektronikk, Vol. 101, No. 1, pp. 113-131, 2005.

[Gan07] I. Ganchev, M. O'Droma, New personal IPv6 address scheme and universal CIM card for UCWW, 7th International Conference on Intelligent Transport Systems Telecommunications (ITST), 2007.

[Gav95] B. Gavish, S. Sridhar, Economic aspects of configuring cellular networks, Wireless Networks, Vol. 1, No.1, pp. 115–128, February 1995.

[Gra02] D. Grace, J. Thornton, G. P. White, T. C. Tozer, Improving spectrum utilisation for broadband services in mm-wave bands using multiple High Altitude Platforms, IEE Conference – ‘Getting the most of the Radio Spectrum,’ 2002.

[Has07] Hasan, P. Racz, C. Morariu, D. Hausheer, B. Stiller, A4C support for commercialization of next generation grid services, ERCIM NEWS, No. 70, pp. 18-19, July 2007.

[Inf04] Information Society DG, European Commission, Building Grids for Europe, August 2004.

[Inf06] J. Infante, M. Oliver, C. Macián, C, Neutral Networks: A real alternative to achieve both effective competition and social benefits?, 16th Biennial Conference of the International

Telecommunications Society: ICT: Opportunities and challenges for Telecommunications (ITS), 2006.

[Inf07] J. Infante, M. Oliver, C. Macián C., Which way to a (judicious) municipal wireless network? An assessment of the different alternatives for municipal participation in wireless local networks, 35th Telecomunications Policy Research Conference, 2007.

[Joh04] K. Johansson, A. Furuskär, P. Karlsson, J. Zander, Relation between cost structure and base station characteristics in cellular systems, IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), 2004.

[Jak03] M. Jakobsson, J.-P. Hubaux, L. Buttyán, A micro-payment scheme encouraging collaboration in multi-hop cellular networks, 7th International Financial Cryptography Conference, pp. 15–33, 2003.

[Kum05] A. Kumar, E. Altman, D. Miorandi, M. Goyal, New insights from a fixed point analysis of single cell IEEE 802.11 WLANs, IEEE INFOCOM, 2005.

[Kel97] F. P. Kelly, Charging and rate control for elastic traffic, European Transactions on Telecommunications, Vol. 8, pp. 33-37, January 1997.

[Kel00] F. P. Kelly, Mathematical modeling of the Internet, Mathematics Unlimited – 2001 and Beyond, B. Engquist and W. Schmid, Eds. Spinger-Verlag, 2000.

[Laa00] C. de Laat, G. Gross, L. Gommans, J. Vollbrecht, D. Spence, Generic AAA Architecture, IETF RFC 2903, August 2000.

[Leh03] W. Lehr, L. McKnight, Wireless Internet access: 3G vs. WiFi? Telecommunications Policy, Vol. 27, pp. 351–370, 2003.

[Mar00] S. Marti, T. Giuli, K. Lai, M. Baker, Mitigating routing misbehavior in mobile ad hoc networks. ACM MOBICOM, 2000.

[Mic02] S. Micali, R. L. Rivest, Micropayments revisited, The Cryptographer's Track at RSA Conference on Topics in Cryptology, 2002.

[Mol02] R. Molva, P. Michiardi, CORE: A collaborative reputation mechanism to enforce node cooperation in mobile ad hoc networks, 6th IFIP Conference on Communications and Multimedia Security (CMS), 2002.

[Moh07] M. Mohorcic, A. Svigelj, Network architectures for load balancing in multi-HAP networks, 4th IASME/WSEAS International conference on Engineering Education (EE'07), 2007.

[Mor06] C. Morariu, M. Waldburger, B. Stiller, An integrated accounting and charging architecture for mobile grids, 3rd International Workshop on Networks for Grid Applications (GridNets), 2006.

[O'Dr04] M. O'Droma, I. Ganchev, Techno-business models for 4G, International Forum on 4G Mobile Communications, 2004.

[O'Dr06] M. O'Droma, I. Ganchev et. al. `Always Best Connected and Served` Vision for a Future Wireless World, Journal of Information Technologies and Control, No. 3-4, pp. 25-37+42, 2006.

[O'Dr07] M. O'Droma, I. Ganchev, Toward a ubiquitous consumer wireless world, IEEE Wireless Communications, Vol. 14, No. 1, pp. 52-63, February 2007.

[Pir03] R. M. Piro, A. Guarise, A. Werbrouck, An Economy-based accounting infrastructure for the DataGrid, 4th International Workshop on Grid Computing, 2003.

[Qia02] D. Qiao and K. G. Shin, Achieving efficient channel utilization and weighted fairness for data communications in IEEE 802.11 WLAN under DCF, IEEE/IFIP International Conference of Quality of Service (IWQoS), 2002.

[San04] T. Sandholm, P. Gardfjäll, E. Elmroth, L. Johnsson, O. Mullmo, An OGSA-based accounting system for allocation enforcement across HPC centers, 2nd International Conference on Service Oriented Computing (ICSOC), 2004.

[San04b] C. Sandvig, An initial assessment of cooperative action in Wi-Fi networking, Telecommunications Policy Journal, No. 28, pp. 579-602, May 2004.

[Sal05] N. Ben Salem, L. Buttyán, J.-P. Hubaux, M. Jakobsson, Node cooperation in hybrid ad hoc networks, IEEE Transactions on Mobile Computing, 2005.

[Sir06] V. Siris and C. Courcoubetis, Resource control for the EDCA mechanism in multi-rate IEEE 802.11e networks, IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2006.

[Vel00] F. Velez, Aspects of Cellular Planning in Mobile Broadband Systems, Phd Thesis, Instituto Superior Técnico, Lisboa, Portugal, December, 2000.

[Vel03] F. J. Velez and L.M. Correia, Optimisation of mobile broadband multi-service systems based in economic aspects, Wireless Networks, Vol. 9, No. 5, pp. 525-533, September 2003.

[Vel07] F. J. Velez, N. Anastácio, F. Merca, O. Cabral, Cost/revenue optimisation of multi-service cellular planning for city centre E-UMTS, IEEE Vehicular Technology Conference (VTC-Spring), 2007.

[Ver06] H. Verkasalo, Emerging trends in the Mobile VoIP business, Seminar on Networking Business, Helsinki University of Technology, 2006.

[Wal07] M. Waldburger, B. Stiller, Legal compliance in commercial service provisioning across administrative domains, 13th EUNICE Open European Summer School and IFIP TC6.6 Workshop on Dependable and Adaptable Networks and Services (EUNICE), 2007.

[Wey05a] A. Weyland, T. Staub, T. Braun, Comparison of incentive-based cooperation strategies for hybrid networks, 3rd International Conference on Wired/Wireless Internet Communications (WWIC), 2005.

[Wey05b] A. Weyland, T. Staub, T. Braun, Comparison of motivation-based cooperation mechanisms for hybrid wireless networks, Computer Communications , pp 2661-2670, 2005.

[Wey06] A. Weyland, C. Latze, T. Braun, T. Staub, Linux implementation and evaluation of a cooperation mechanism for hybrid wireless networks, 6th International Workshop on Wireless Local Networks, 2006.

[Wan07] N. Wang, I. Ganchev, M. O'Droma, An architecture for the provision of incoming call connection service in UCWW, IEEE Vehicular Technology Conference (VTC-Spring), 2007.

[Wes06] S. Wesner, J. Jähnert, M. Escudero, Mobile collaborative business grids – A short overview of the Akogrimo project, Whitepaper, Akogrimo Consortium, 2006, http://www.akogrimo.org/.

[Yan02] H. Yang, X. Meng, S. Lu, Self-organized network-layer security in mobile ad hoc networks, ACM Workshop on Wireless Security, 2002.

[Zho03] S. Zhong, J. Chen, Y.R. Yang, Sprite: A simple, cheat-proof, credit-based system for mobile ad-hoc networks, IEEE INFOCOM, 2003.

The COST 290 documents can be downloaded from the link www.cost290.org. The COST 290 documents referenced in this Chapter are listed below:

[TD(04)004] V. A. Siris, C. Courcoubetis, Resource control for loss-sensitive traffic in CDMA networks.

[TD(05)006] J. Ferreira, F. J. Velez, Deployment Scenarios and Applications Characterisation for Enhanced UMTS Simulation.

[TD(05)027] A. Weyland, T. Staub, T. Braun, Comparison of Incentive-based Cooperation Strategies for Hybrid Networks.

[TD(05)041] F. McEvoy, I. Ganchev, M. O'Droma, New third-party AAA framework and signaling protocol for 4GWW.

[TD(05)042] B. Stiller, Akogrimo – Business Models and Charging for Grid Services.

[TD(05)051] O. Cabral, F. J. Velez, G. Hadjipollas, M. Stylianou, J. Antoniou, V.Vassiliou, A. Pitsillides, Enhanced UMTS Cost/Revenue optimisation in offices Scenarios.

[TD(05)054] G. Kandus, A. Svigelj, M. Mohorcic, Telecommunications over High Altitude Platforms.

[TD(06)012] B. Bellalta, M. Meo, M. Oliver, Call Admission Control in IEEE 802.11e EDCA-based WLANs (Initial Steps).

[TD(06)019] J. Infante, M. Oliver, C. Macián, Taxonomy for Wi-Fi Initiatives: Models and SWOT analysis.

[TD(06)042] C. Morariu, An Integrated Accounting and Charging Architecture for Mobile Grids.

[TD(06)045] O. Cabral, F. J. Velez, C. Franco, R. Rei, Enhanced UMTS Urban Cellular Planning Optimisation of Multi-service Enhanced UMTS Based in Economic Issues.

[TD(06)054] P. Flynn, I. Ganchev, M. O'Droma, Service Advertisement, Discovery and Association over Wireless Billboard Channels in future UCWW.

[TD(07)007] V. A. Siris and C. Courcoubetis, Resource Control for the EDCA Mechanism in Multi-Rate IEEE 802.11e Networks.

[TD(07)047] F. J. Velez, N. Anastácio, F. Merca, O. Cabral, Cost/Revenue Optimisation of Multi-service Cellular Planning for Business Centre E-UMTS.