COMPETITION BETWEEN EMERGING WIRELESS NETWORK TECHNOLOGIES: CASE HSPA VS. WIMAX IN EUROPE

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Abstract

The rapid evolution of wireless networking technologies has opened up new possibilities for wireless delivery of multimedia services and content. In addition to the standardization efforts of 3GPP and 3GPP2 on third generation mobile networks, new broadband wireless access technologies such as WLANs, WiMAX, Flash-OFDM, and DVB-H are emerging as alternative means to provide services to mobile users. These technologies are also offering possibilities for new players to enter the markets, inducing competition and possibly threatening the businesses of established players.

In this paper, a conceptual framework is constructed for the analysis of emerging wireless technologies and their market potential. The framework is then applied to compare two different technology scenarios: an evolutionary 3GPP-based HSPA-scenario and a disruptive WiMAX-based scenario.

Our framework emphasizes the importance of analyzing the complementary and substitutive nature of technologies, from four essential viewpoints. The end-user viewpoint aims to identify those use cases where the respective technologies can be used to complement and/or substitute existing technologies. The technology viewpoint focuses on analyzing and comparing the relative techno-economic characteristics of the technology alternatives. The value network viewpoint focuses on analyzing the capabilities of the industry players to deliver a "whole product" to the end-users, consisting of networks, terminals, and applications and content. Finally, the viewpoint of policy and regulation focuses on the external factors having an effect on both the capabilities of the technologies, as well as the strategies and decisions of players in the value network.

Results from the case analysis show that HSPA and WiMAX are mainly substitutes rather than complements from both the end-user and technological performance point-of-view. The outcome of the technological battle between them might have an effect on the structure of the whole mobile industry.

1. Introduction

Considerable uncertainty exists about the future evolution of mobile networks and services. From the simple voice and text messaging services of today, a move towards richer multimedia and broadband services is anticipated. A number of partly complementary, partly substitutive network technologies are emerging to enable these services, each with their strengths and weaknesses, as well as proponents and opponents.

The evolution of wireless technologies is very dependent on standardization work carried out by a number of different organizations. 3GPP and 3GPP2 are developing specifications for wide-area mobile networks, based on the WCDMA and cdma2000 technologies, respectively. These specifications aim to provide an evolutionary path for 2G mobile technologies (i.e. GSM and cdmaOne) allowing 2G operators to utilize their existing infrastructure and smoothly upgrade their networks to support new services.

In addition, three IEEE working groups are of special importance. The 802.11 working group develops standards for wireless local area networks (WLANs), whereas the 802.16 working group is responsible for wireless metropolitan area networks (WMANs), both fixed and mobile. Products conforming to these standards are certified and promoted by Wi-Fi Alliance and WiMAX Forum, giving the standards their well-known trade names. Yet another working group, 802.20, is developing a standard for mobile broadband access networks.

A number of other wireless technologies are available, as well. Bluetooth has gained popularity in providing short-range connectivity between various devices. A group of standards, including DVB-H, have been proposed for mobile broadcasting and television services. In addition, from the end-user point of view, wireless technologies are both complemented and substituted with a number of wired technologies. For example, many use cases of Bluetooth can be substituted with USB. The mobile broadcasting business is challenged by the “podcasting” model, i.e. locally filling the mobile terminal’s storage with desired content, and viewing it when convenient.

When two or more technologies are close substitutes and targeted at the same markets, a technology battle often takes place. The outcomes of these battles determine also the faith of complementary goods and services offered around each of the competing alternatives (Suarez 2004). Therefore, analyzing the potential of emerging technologies is valuable not just for the companies developing them, but also various other players in the industry.

A number of studies have analyzed the techno-economic performance and resulting cost level of emerging network technologies, either to validate a certain technology path (Katsianis et al. 2001) or to compare two or more technological alternatives (Monath et al. 2003). This group of techno-economic studies typically focuses on quantitative forecasting and modeling of revenues and costs in certain selected market scenarios.

Lehr & McKnight (2003) compare and contrast 3G and Wi-Fi technologies for delivering broadband wireless Internet access services, from technical, service, business model, and spectrum policy viewpoints. Bauer & Lin (2004) propose a framework for the study of next-generation wireless services and related policy issues, in which the evolution of wireless industry is seen to be determined by the dynamic interaction of technology, public policy, supplier strategies, and consumer behavior. Similarly, Yuan et al. (2006) suggest a framework that integrates technology, market demand, business model, and government policy perspectives for a comparative analysis between two wireless technology alternatives.

In this study, a conceptual framework for the analysis of emerging wireless technologies is constructed, integrating the viewpoints of end-user, technology, value network, and public policy. The framework is then applied to analyze and compare two different technology scenarios: an evolutionary 3GPP-based HSPA scenario and a potentially disruptive WiMAX-based scenario.

2. Conceptual framework

In our view, the analysis of the emerging wireless technologies has to take into account the viewpoints of 1) end-user, 2) technology, 3) value network of the industry, and 4) policy and regulation. Each of these viewpoints is discussed in more detail in the following sections. Finally, a framework integrating these viewpoints is constructed.

2.1 End-user

End-users, both consumers and professionals, have nowadays a number of digital, network-connected devices in use, each one capable of performing a set of partly different, partly the same tasks. As an example, for reading e-mails or surfing the web, one can utilize e.g. desktop/laptop PC at home and at the office, and mobile phone when on the move. Regarding wireless technologies and services, a common vision for the future is one where the users are “always best connected” (see e.g. Gustafsson & Jonsson 2003).

In general, the end-users have a need to use certain applications in certain contexts, i.e. time and place. In different contexts, different sets of devices are available, with different characteristics regarding e.g. screen size and usability. Furthermore, the coverage, data rate, and price of available network connections depend on the device and the context. Accordingly, also the end-user preferences vary between contexts. An exemplary mapping of preferred terminal categories to applications and contexts is shown in Table 1.

Table 1: Mapping of end-user terminal categories to applications and contexts

Application / Context	At home	At office	"Hotspot"	On-the-move
Calling	D, L, **M, F**	D, L, **M, F**	L, **M**	**M**
Watching a video (e.g. news)	**T**, D, L, M	D, L, M	L, M	M
Playing a network game	**T**, **D**, L, M	D, L, M	L, M	M
Reading e-mail	**D, L**, M	**D, L**, M	**L,** M	**M**
Surfing the Internet	**D, L**, M	**D, L**, M	**L,** M	**M**

D = Desktop, L = Laptop, M = Mobile phone, F = Fixed line phone, T = Television (**Bold** = preferred device)

From the end-user point-of-view, different devices are complementary in that each is preferred in different contexts and for different applications. They are, however, also competing with each other to be the preferred one in as many situations as possible. This competition between devices has an effect also on the competition between network technologies.

In addition to the terminal categories mentioned above, a number of other alternatives exist. For example, personal digital assistants (PDAs, like HP iPaq), portable gaming devices (Nintendo Gameboy, Sony PSP), and Internet tablets (Nokia 770, Microsoft UMPC) are available in the market, each one with their own characteristics and better or worse suitability for different applications. In the future, the variety of wireless devices is expected to extend further.

Regarding wireless technologies, currently the most interesting terminal categories are mobile phones and laptops, due to their high market penetration and inherent need to be used unattached to wires and cables. Both types of terminals may have a number of different wireless networking interfaces embedded in them. For example, a modern mobile phone may include GSM/GPRS, EDGE, and WCDMA for wide-area connectivity, Bluetooth for connecting to laptop and peripherals, WLAN for high-speed local area data, and DVB-H for receiving broadcasted video streams.

2.2 Technology

The question of complementarity and competition often comes up when analyzing and comparing wireless networking technologies (see e.g. Lehr & McKnight 2003). A corollary is that if the technologies are complementary they will be able to co-exist peacefully - otherwise they will engage in a battle of technological dominance.

To be useful in the analysis, we first have to define the concept of technical complementarity. In basic economics, as opposite to substitutes, two goods are considered to be complements if the demand for one decreases as the price of the other increases. In mathematics and e.g. set theory, the complement of a set includes all elements that are not in the set. For analyzing technical complementarity, the latter association is perhaps more appropriate.

Figure 1 illustrates three technologies (A, B, and C), which are mapped into a graph based on their performance and capabilities in two different dimensions. Often, dimensions such as mobility and data rate have been used when visualizing wireless technologies' capabilities.

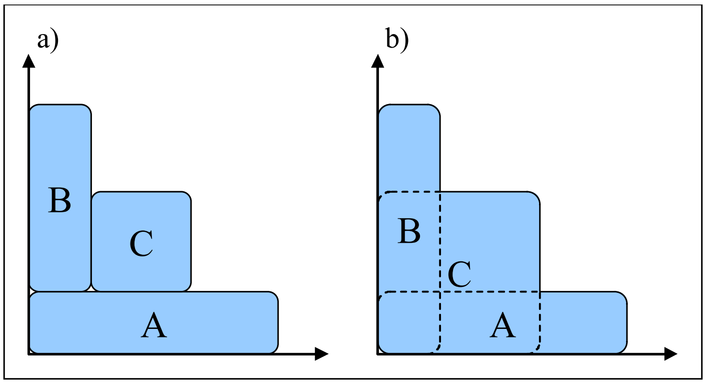

Figure 1: Illustration of full and partial technical complements

Figure 1a shows a situation where the three technologies truly complement each other, i.e. are completely non-overlapping. In this case, the technologies each have their own specific application areas, in which they face no competition from the other technologies. Figure 1b, on the other hand, illustrates a situation in which the three technologies each have their own technical strengths and weaknesses compared to the other two, but are also partly overlapping (i.e. substitutive) with each other.

In reality, the latter situation is far more common. This is the case e.g. when mapping 3G and WLAN in a similar graph, using mobility and data rate as the axes. Although 3G offers better mobility and WLAN better data rates, the technologies overlap in applications where no mobility and only modest data rates are required. Thus, regarding technological performance and suitability for different end-user applications, wireless technologies are rarely fully complementary but at least partly substitutive.

Mobility and data rate are, although important, obviously not the only parameters by which the wireless technologies differ. In a thorough comparative analysis, a number of other qualities have to be considered, including cost level (e.g. per square-km or per subscriber), power consumption, and quality of service, among others.

For the purposes of this paper, we define a technology to be *technically complementary* to another, if it can be used to provide a service that cannot be provided with the other technology. On the contrary, we define a technology to be *technically substitutive* to another, if it can be used to provide a service that can also be provided with the other technology.

2.3 Value network

A common starting point for analyzing industries is to draw a "map" of different players, roles, and relationships required to provide the end-user with desired product or service. These maps have often been named as e.g. supply chains or value chains. In the past few years, the concept of value networks has been widely used in academic studies, and a number of different value network models have been proposed (see e.g. Maitland et al. 2002, Li & Whalley 2002).

According to Nalebuff & Brandenburger (1996), a firm's *value net* consists of customers, suppliers, competitors, and complementors, as illustrated in Figure 2. A firm should consider another player as a *competitor* when customers value the firm's product less when they have also the other player's product. On the opposite, a *complementor* is a player whose product makes the customer value the firm's product more.

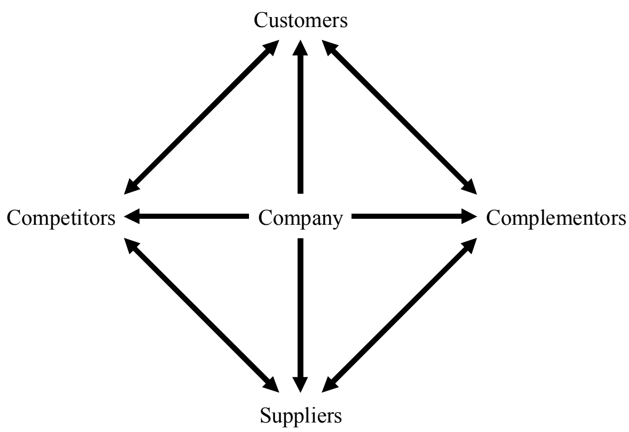

Figure 2: Players in a company's value net (Nalebuff & Brandenburger 1996)

For the purposes of this paper, we have constructed a simplified mobile value network model, as depicted in Figure 3. The model stresses the complementarities between networks, terminals, and applications and content in creating a complete service offering to the end-users. Competition between players is not explicitly shown; it is considered to take place between different players taking the same role.

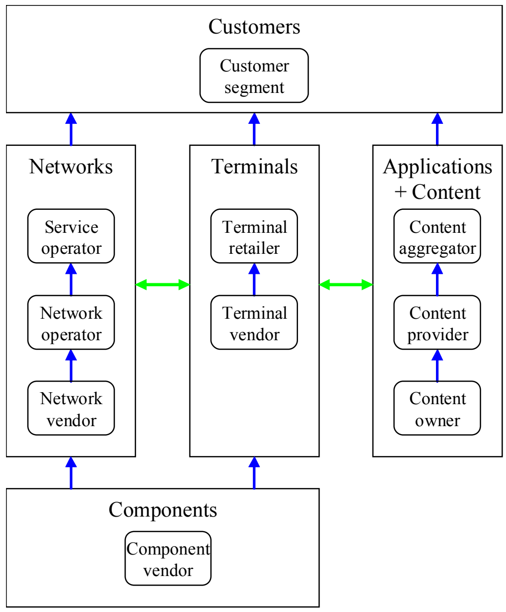

Figure 3: Simplified mobile value network

Our value network model shares this view of Li & Whalley (2002, p.465) according to which *"the value network can be seen as a series of inter-twined value chains where some nodes are simultaneously involved in more than one value chain"*. The rounded boxes in Figure 3 should be interpreted as roles, not as separate players as one player may take one or many roles. For example Nokia, a leading wireless technology vendor, is both a network vendor and a terminal vendor. In some emerging markets, it is increasingly becoming a network operator as well. Similarly, incumbent mobile operators take the role of both network operator and service operator, and are also involved in provisioning of terminals and content.

Our value network model and concept of complements also highlight the importance of providing a "whole product", defined by Moore (1991, p. 119) as *"the minimum set of products and services needed to fulfill the compelling reason to buy for the target customer"*. Clearly, in order to be of value to the end-user, both the terminals and networks must be available, as well as the applications and content desired to be run over this infrastructure.

2.4 Policy and regulation

For the purposes of this study, we have identified two broad categories of policy decisions having an effect on the competition between wireless technologies: spectrum policy and service vs. infrastructure-based competition.

Spectrum policy

Spectrum policy decisions are related to the following three broad issues (Analysys 2004): spectrum allocation (i.e. what types of uses should be allowed), spectrum assignment, (i.e. who should be allowed to operate the frequencies), and centralized vs. decentralized decision-making (i.e. should decisions on allocation and assignment be made by the state or be devolved to users).

Spectrum policy in Europe has been traditionally based on a centralized "command-and-control" approach, in which both allocation and assignment decisions are made by the government. Spectrum trading would allow the transfer of spectrum usage rights between parties in a secondary market. Service and technology neutrality, or spectrum liberalization, on the other hand, would devolve decisions over spectrum allocation to users, allowing the market to determine how spectrum is used. (Analysys 2004)

The European Commission is currently planning to shift its spectrum policy towards a more market-based approach. In EU's view, the principles of technology and service neutrality should be applied and users should be given more power in deciding how to use the spectrum. Regarding spectrum trading, the Commission proposes to introduce spectrum markets in the EU by 2010. (European Commission 2005)

In Europe, the spectrum allocations for mobile broadband services have not yet been finalized. For 3G-based systems a continent-wide harmonized spectrum band exists, whereas for alternative technologies the situation may differ from country to country.

Service vs. infrastructure-based competition

In general, the regulation in the telecommunications industry identifies two main types of markets: retail markets providing services or facilities to end-users and wholesale markets providing access to facilities to other operators. In our value network constellation (Figure 3) this was visualized by separating the network operator and service operator roles in the network provisioning part.

Service-based competition takes place when new entrant operators utilize the incumbent's existing network infrastructure to offer services to end-users. In infrastructure-based competition, the new entrants build and operate their own access network infrastructure, based on the same or alternative technologies as the incumbent.

The investment decisions of potential new entrants can be affected by regulating the existing wholesale markets and e.g. forcing open access to network infrastructure provided by incumbents.

Thus, heavily regulated wholesale markets based on e.g. 3G network infrastructure technologies may discourage investment to alternative network technologies.

2.5 Integrated framework

Based on the discussion presented above, we have constructed a conceptual framework for analyzing competition between emerging wireless technologies. An illustration of the framework is shown in Figure 4.

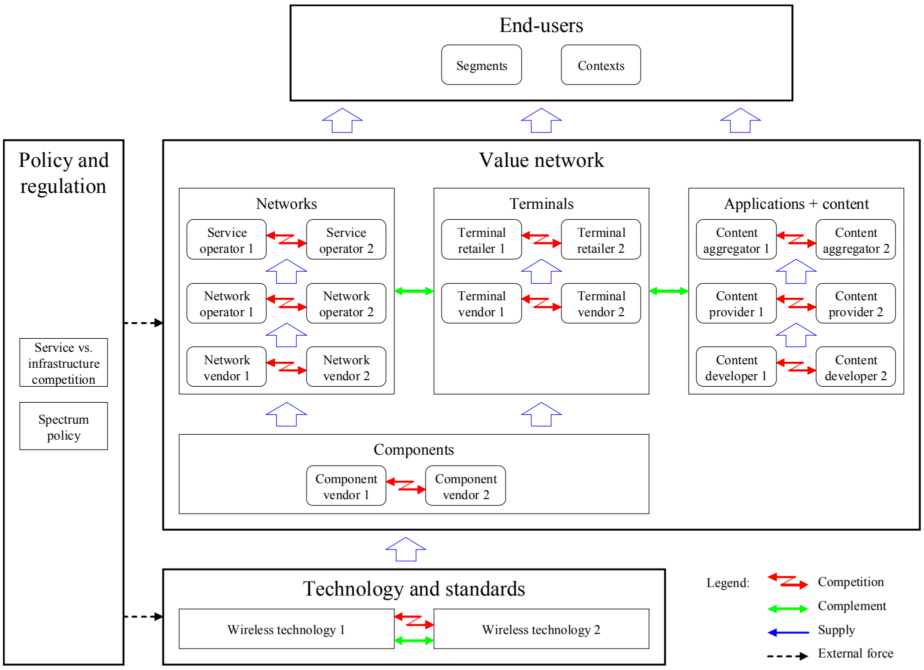

Figure 4: Conceptual framework for analyzing competition between emerging wireless technologies

The framework highlights the importance of analyzing the competitive / complementary relationships of technologies and players in many different levels.

Techno-economic performance of the technologies and standards forms the basis for their acceptance among the players in the industry. Technical superiority is, however, not sufficient for success. As new technologies emerge, each player in the value network considers them in light of their existing assets, alternative technologies, existence of competitors and complementors, and demand from their customers. Thus, it is not sufficient to match only the end-user needs with the technical characteristics of the standards; the technology has to find acceptance on all levels of the value network.

3. Mobile broadband services: HSPA vs. WiMAX

In this chapter, we apply the conceptual framework constructed above to perform an initial analysis of the success potential of and competition between two emerging wireless technologies: High Speed Packet Access (HSPA, a combination of High Speed Downlink Packet Access HSDPA and High-Speed Uplink Packet Access HSUPA) specified by 3GPP as an evolutionary development to WCDMA systems, and IEEE 802.16e-based systems, also known as mobile WiMAX. At this stage, our analysis is limited to data and information publicly available from various sources; future work will aim to validate and deepen these findings by interviews and more detailed quantitative modeling.

3.1 End-users

The end-user viewpoint to the analysis aims to identify those use cases (time, place, device, application) where the respective technologies either complement or substitute existing technologies and/or one another. The market is considered to consist of both business users and consumers willing to have broadband connectivity to their laptops and mobile phones.

Practically all laptops have an integrated Ethernet interface and majority of today's models has an integrated WLAN interface, as well. From the end-user point-of-view, these are clearly the most important substitutes to WiMAX and HSPA. Whereas Ethernet can be used only when a cable is conveniently available, WLAN is often usable throughout an office or home. For these use cases, the alternative technologies offer little or no additional value compared to existing ones. For the laptop users, demand for alternative wireless technologies emerges mainly when the laptop is to be used on-the-move or in hotspots with no WLAN coverage. Increased availability of public WLAN networks therefore decreases the market opportunity for WiMAX and HSPA.

In Europe, the majority of mobile phones include GSM and GPRS capabilities, while EDGE and WCDMA are becoming increasingly available. A small number of mobile phone models have also a WLAN interface. From the end-user point-of-view, mobile broadband technologies can provide additional value to most mobile data services, and possibly enable also some new services.

Although Bluetooth is not considered to be a direct substitute to mobile broadband technologies, it enables a special type of substitution effect between the technologies used in laptops and mobile phones. If the end-user has Bluetooth in the laptop as well as in the mobile phone the data capabilities of the phone can be utilized also by the laptop, decreasing the demand for a device-specific connection.

From the end-user point-of-view, comparison between HSPA and WiMAX does not reveal any major differences between the two technologies: both are aimed to similar use cases. The initial target for both technologies is to provide broadband connectivity to the laptops of business users, and at later stage extend the market towards consumers and mobile phones. Therefore, our conclusion is that from the end-users point-of-view the two technologies are substitutive.

3.2 Technology and standards

The technology and standards viewpoint focuses on analyzing and comparing the relative techno-economic characteristics of the technology alternatives.

As mobile WiMAX equipment is not yet available, no real-life measurements have been made to compare the technologies side-by-side, leaving room for speculations, biased opinions, and hype. Proponents of both WiMAX and HSPA have published results from simulation studies about the performance of the standards ending up, not surprisingly, at different and contradictory results (see e.g. WiMAX Forum 2006, Belk 2006). Here, we limit our analysis to the factors having an effect on the key technical parameters of the systems, including coverage, capacity, cost, and service quality.

Coverage and capacity

For coverage calculations, the concepts of *link budget* and *path loss* are valuable. Link budget calculations take into account the transmitter power level and receiver sensitivity, as well as all the elements between them in the radio system causing the radio signal to gain or lose its power. A link budget calculation yields the maximum path loss (in dB) that may take place without degrading the quality of the transmitted data. Together with a suitable path loss model, this value provides the link (or cell) range in km. The link/cell range decreases exponentially as the carrier frequency increases.

The capacity of a wireless system can be determined by its *spectral efficiency* (in bps/Hz) and *channel bandwidth* (in Hz), the latter being dependent on both the system specifications and the size of the spectrum allocation. Both coverage and capacity of wireless networks are therefore dependent on the technical characteristics of the systems as well as on the spectrum allocations.

Table 2 lists the key parameters affecting the performance of HSPA and mobile WiMAX systems.

Table 2: Parameters affecting the performance of HSPA and mobile WiMAX systems

	HSPA	**Mobile WiMAX**
Available frequency bands in Europe	2 GHz band: 1.920 – 1.980 MHz / 2.110 – 2.170 MHz (2 x 60 MHz)	3.5 GHz band: 3.410 – 3.600 MHz (190 MHz)
Channel bandwidth	5 + 5 MHz (FDD)	5 MHz or 10 MHz (TDD)
Typical allocation per operator	15 + 15 MHz	28 + 28 MHz
Spectral efficiency	Uncertain	Uncertain

As discussed earlier, the real-life spectral efficiency figures for both HSPA and WiMAX systems have not been reported, and considerable uncertainty exists how efficient the systems will be in different environments, for different traffic patterns, and for different amounts of users. According to simulation studies carried out by WiMAX Forum, the spectral efficiency of mobile WiMAX systems would be in the range of 1.10 – 1.91 bps/Hz for the downlink and 0.69 – 0.84 bps/Hz for the uplink, compared to 0.78 (downlink) and 0.30 (uplink) for HSPA, respectively (WiMAX Forum 2006). According to Qualcomm's simulations (Belk 2006), HSDPA spectral efficiency performance is 15%-35% better than that of Mobile WiMAX. At this point, we will leave this controversial topic open.

Mobility and network architecture

Another important dimension in the technological comparison is the mobility provided by the systems. HSPA's roots are in the mobile industry, whereas mobile WiMAX is a further development of the fixed WiMAX standards.

The HSPA and 802.16e standards define only a radio interface comprising of physical and MAC layer specifications. Higher layer protocols are required to take care of mobility management in the network. HSPA relies on the 3GPP specifications and network architecture in providing mobility. In mobile WiMAX case, the Network architecture Working Group (NWG) of the WiMAX Forum has specified the required architecture and protocols for providing mobility. Figure 5 shows simplified architectures for the two systems.

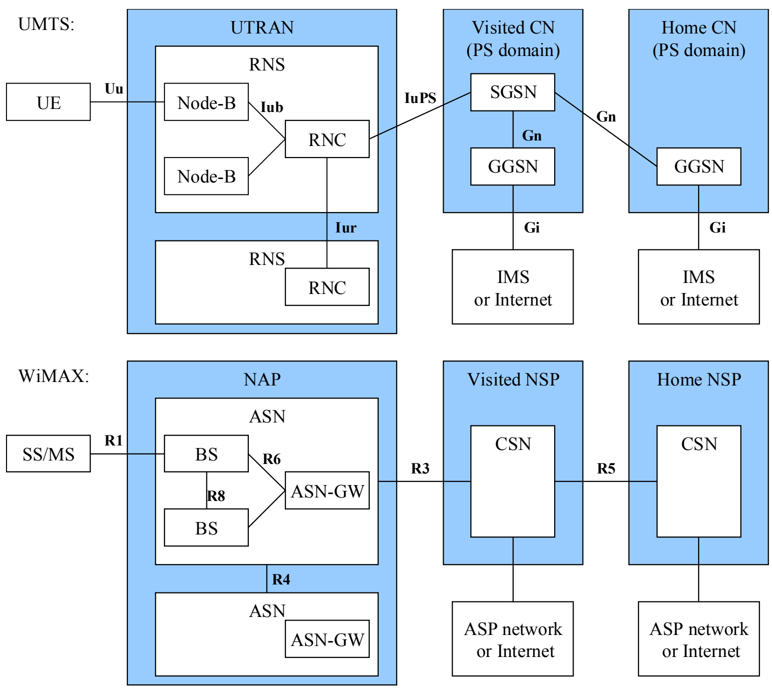

Figure 5: Network architectures for UMTS and Mobile WiMAX systems

As shown in the figure, the network architectures are very similar on a high level. The protocols used in each interface are, however, different. Whereas HSPA builds on the mobility management functions of UMTS, mobility in WiMAX is based on IP technologies.

The WiMAX network architecture has been designed so to facilitate interworking between WiMAX and 3GPP-based networks. In this case, the Access Service Network Gateway (ASN-GW) would directly connect to either the SGSN or GGSN of the 3G core network. On the other hand, HSPA does not necessarily require a complete 3G core network behind it; more "flat" network architectures have already been productized by network vendors. Therefore, both technologies can be provided as lighter "standalone" versions or as integrated to the existing core networks of established operators.

Based on our initial analysis, the technical differences between HSPA and mobile WiMAX are not seen as very significant. The two technologies are seen to be technically substitutive to one another, and technical complementarities between them are quite small.

3.3 Value networks

The value network viewpoint focuses on analyzing the capabilities of the industry players to deliver a "whole product" to the end-users, consisting of networks, terminals, and applications and content.

Networks

Component manufacturers and network vendors are in a key role in providing competing lines of products for the network operators. Ericsson, Nokia-Siemens, Alcatel-Lucent, and Motorola have been the most important vendors for the 2G and 3G networks, and each of these companies has also launched product lines supporting HSPA.

HSPA systems hold the first-mover advantage in the market. The first HSDPA networks were launched in late 2005, and by July 2006 a total of 48 commercial HSDPA networks were available in 33 countries, including 15 of the 25 EU countries (GSA 2006a). Many of the Europe's largest mobile operators are currently upgrading or planning to upgrade their 3G networks to support HSDPA. First HSUPA products are expected to be available in 2007.

Commercial WiMAX deployments are currently based on products conforming to the 802.16-2004 standard and supporting only fixed end-user terminals in both line-of-sight and non-line-of-sight environments. The network vendors for fixed WiMAX products are relatively smaller compared to the 2G/3G mobile network vendors, including players such as Alvarion, Airspan, and Redline Communications. The networks have been mainly built to provide fixed broadband services to areas not covered by DSL or cable infrastructure.

As of July 2006, mobile WiMAX network equipment is not yet available in the market, and no commercial networks have been launched. According to WiMAX Forum, the networks are "expected to begin rolling out in late 2006 and early 2007" (WiMAX Forum 2006). Alcatel-Lucent, Nokia-Siemens, and Motorola have all announced to support WiMAX in their future network products.

Mobile WiMAX has not yet found major supporters among the operators in the European markets, and no wide-scale network deployments have been announced. Whereas network vendors appear to consider WiMAX as a complement to their product portfolios, large mobile operators such as Vodafone are strongly supporting HSPA and showing little support for WiMAX. Therefore, it seems that WiMAX is complementary from the viewpoint of network vendors, but considered as competitive to established mobile operators. For new entrants or e.g. fixed-line operators, WiMAX could be the technology of choice over HSPA.

Terminals

First HSDPA terminals were launched in 2005, and currently around 50 different HSDPA-capable devices are available. These include both PC cards and USB adapters for laptops, as well as mobile phones from e.g. Samsung, LG, and Motorola. In addition, laptop manufacturers such as Acer, Dell, HP, and Lenovo, have launched HSDPA-enabled laptops, most in partnership with mobile network operators (GSA 2006b). Therefore, it seems that the major handset vendors can quite easily add HSPA terminals to their portfolio.

Mobile WiMAX terminals are yet to be introduced to the market. The first terminals will include separate DSL modem-like boxes as well as PC cards. Intel's role as the leading component manufacturer for laptop PCs is important for WiMAX terminal adoption, and it's decision to include WiMAX as a standard feature to its laptop designs, similarly to WLAN, will most certainly increase the demand for networks, as well.

Both Motorola and Nokia have announced to support WiMAX, and are expected to support it in some of their future handsets.

Applications and content

From the applications and content point of view, HSPA and WiMAX have quite similar standings. Both are initially aimed to laptop users to provide them with basic broadband internet access services. Later, depending on the strategies of the respective network/service operators, the service portfolio might be extended with value-added services and exclusive content offerings. Many operators are currently investing into IP Mobile Subsystem (IMS) infrastructure, services enabled by which can be offered both via HSPA and WiMAX accesses.

Table 3 summarizes the characteristics of the value networks supporting HSPA and WiMAX technologies, respectively.

Table 3: Players in HSPA and WiMAX value network characteristics

	HSPA	**Mobile WiMAX**
--- Components ---		
Market status	Components available from many manufacturers	First chipsets announced in January 2006
Leading vendors	Qualcomm	Intel
--- Networks ---		
Market status	Commercial networks launched in late 2005	No commercial network equipment available
Leading vendors	Ericsson, Alcatel-Lucent, Nokia-Siemens, Motorola	Alvarion (fixed WiMAX 802.16d) Motorola?
Network/service operators	Incumbent operators with 3G licenses	3.5 GHz licensees with various backgrounds. No major support or deployment plans announced.
--- Terminals ---		
Market status	Both laptops and handsets available	No terminals available.
Leading vendors	Samsung, LG, Motorola	Intel-based laptop vendors Motorola?
Terminal providers	Mostly incumbent operators bundling the terminals with data service subscriptions	Laptop retailers WiMAX operators
--- Applications and content ---		
Market status	Basic broadband internet access services available	Basic broadband internet access services to appear first
Content providers/aggregators	Access to both operator's own services as well as open access to Internet	Mainly open access to Internet

Our analysis on the value networks and existence of complementors shows that HSPA is currently in better position to provide a full product to end-users, enjoying a clear first-mover advantage and strong support from all parts of the value network.

The WiMAX ecosystem is very dependent on the commitment of Intel as the main enabler of components to WiMAX-enabled terminals. On the network side a number of vendors are expected to launch products, but major commitment from the operator side is still missing.

3.4 Policy and regulation

Policy and regulation are considered as external factors having an effect on both the capabilities of the technologies, as well as the strategies and decisions of different players in the value network.

Spectrum policy

As discussed, allocation of spectrum to different systems is in a key role in defining their technical performance. HSPA operates around 2 GHz on the IMT-2000 bands, whereas the WiMAX systems will be initially using the 3.5 GHz frequency bands. Spectrum-wise, the 2 GHz band provides better coverage and the 3.5 GHz band higher capacity.

In the future, the IMT-2000 extension band between 2500 and 2690 MHz will provide more spectrum for broadband wireless systems. On the European level, the Electronic Communications Committee (2005) has decided to designate the band for terrestrial IMT-2000/UMTS systems, and make it available for these systems as from January 2008.

However, the European Commission is increasingly supporting the principles of technology and service neutrality in spectrum management. According to the Radio Spectrum Committee (2005), *"new technologies, including particularly those which were developed after the identification of IMT-2000 technologies in 1999, should not be excluded, provided they do not cause interference and are compatible with the channelling plan developed based on IMT-2000."* A recent consultation by the Commission and the received answers clearly indicate that the companies with stakes in the 3GPP-based technologies would want to exclude alternative technologies from the band, whereas companies with stakes in WiMAX are strongly in favor of technology neutrality. Also the positions of different European countries differ significantly.

Allowing non-IMT-2000 technologies on the IMT-2000 extension band or parts of it (i.e. the so-called centre gap between 2570 – 2620 MHz) would be of benefit to WiMAX. Whether or not this will happen in some or all European countries remains to be seen.

Service vs. infrastructure-based competition

Regarding HSPA and WiMAX, the regulator's view on the relative advantages and disadvantages of service and infrastructure-based competition may affect the technology choices of operators. As HSPA systems will be deployed ahead of WiMAX, entrants to the market are effectively selecting between three options: 1) to build their own WiMAX network, 2) to build their own HSPA network, and 3) to lease capacity from the existing HSPA network operators and act only as service operators. If open access is mandated and the wholesale prices are regulated, the incentives to invest in own network infrastructure might be lower, working in favor of the HSPA technology. Also in this case, regulation between different European countries is likely to differ.

4. Summary and conclusions

In this paper we have constructed a framework for analyzing emerging wireless technologies. The framework keeps a holistic view to the analysis task, highlighting the importance of analyzing the complementary and substitutive properties of technologies from various viewpoints. The framework is considered to be widely applicable for analysis of future networking technologies.

The framework was also applied to carry out an initial comparative analysis between two alternative mobile broadband technologies: HSPA and mobile WiMAX. From the end-user point of view, the two technologies are close substitutes; both are enabling same types of services for the same devices and contexts. Differences in the technological performance are also considered to be quite small. This suggests that the technologies will engage in a technological battle, rather than coexist and complement each other.

The value network supporting HSPA is seen as stronger and more capable of providing a full mobile broadband service to the European market, consisting of networks, terminals, and applications and content. HSPA holds also the first-mover advantage. Current spectrum policy is favorable to HSPA, although the trend towards technology-neutrality might improve the position of WiMAX.

HSPA can be seen as an evolutionary step in established mobile operator's technology roadmaps, whereas WiMAX is more of a disruptive technology likely to be initially utilized by other players and new entrants. The outcome of the technological battle might therefore have profound effects on the structure of the whole mobile industry.

The main contribution of this paper, the conceptual framework, was constructed based on a literature review and personal reasoning of the author, and is seen to be only in its initial form. In the future, the framework will be tested, validated, and improved by interviewing different stake-holders of the industry.

Further work includes also widening the scope of the analyses to other technology cases. In addition to 3GPP evolution and WiMAX, a number of other interesting developments are taking place in the mobile market regarding wireless technologies. The evolution of WLANs, emergence of mobile broadcasting systems based on DVB-H, and proprietary challengers such as Flash-OFDM are seen as fruitful topics to be analyzed.

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