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THE ECONOMICS OF WIRELESS NETWORKS

Assessing the rapidly changing economics of the wireless industry.

The field of mobile wireless communications is currently one of the fastest growing segments of the telecommunications industry. Until a few years ago, the popularity of such systems was mainly due to their ability to offer voice communications to mobile users. However, the current trend toward the wireless Internet is having a significant impact on the world of mobile wireless networks. The movement toward integration of wireless networks and the Internet has resulted in significant change for the wireless industry—we summarize the main factors affected by this change here [4].

In the terminal manufacturer realm, there has been increased movement toward Internet appliances. It is expected that current wireless terminals will be substituted by Internet-enabled devices, such as Internet-enabled phones and digital assistants. Whereas today one of the main goals of terminal manufacturers is reduction in size and battery power consumption, in the future the target will also be terminals that support high-speed data services.

Mobile terminals are expected to continue to experience a sales increase despite the previously projected reduction in the growth rate of the customer base. This is to be expected, since customers are likely to change their terminals every few years in order to be able to keep up with the new services offered by mobile carriers. Mobile terminals will continue to be based on silicon technology with a further reduction in form factors and prices.

Increased competition from Asian manufacturers is expected. Because Japan used a different 2G standard from the rest of the world, Japanese firms were left out of the initial international competition for 2G terminals. However, this has changed, as evidenced by the fact that many of the first trial 3G system deployments were made in Japan and by the announcement of the world's biggest operator, Vodafone, that 80% of its 3G terminals will be Japanese.

For infrastructure manufacturers, there will be increased market opportunities. The mobile infrastructure market is likely to rapidly increase in size due to the deployment of the next generations of wireless networks. According to Motorola estimations, this market will grow to $200 billion dollars until 2006, four times the size it achieved in 1999 [4]. However, other estimations recently appeared that lower this number to $35 billion by 2008 (see www.3gnewsroom.com/3gnews/feb_04/news_4161.shtml). Along with the increased market opportunities, there will be increased entry barriers. The increased complexity of infrastructure equipment for the next generations of wireless networks and the increased demand for such equipment is likely to favor companies that have achieved a large market share.

The mobile carriers will face the greatest market challenges in the new era of the wireless industry. They must adapt to the reducing growth rates of the subscriber base and the declining prices. The expected adoption of the wireless Internet as a primary means of revenue will require mobile carriers to perform a number of additional roles in order to remain competitive, including:

- **The ISP role.** Mobile carriers must carefully examine developments in the early phases of consumer use of the Internet. Considering how local telephone companies in the U.S. missed the opportunity to become major ISPs when AOL emerged as the initial dominant provider, mobile carriers will want to ensure a similar situation does not occur with the wireless Internet. This means reduction of wireless Internet prices. However, it will be difficult to match or reduce the costs to equal those of the wired Internet because wireless bandwidth is a scarce and expensive resource.

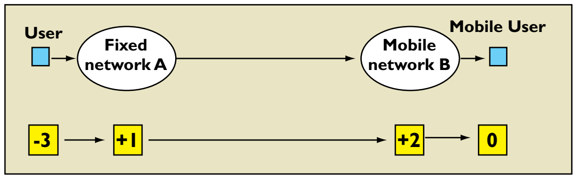

Figure 1. The calling party pays for usage of both the fixed and the mobile networks.

- **The portal role**. Mobile carriers will also have to run their own portals to the wireless Internet world. In this case, it is likely that portals already flourishing on the wired Internet will have an advantage over those of mobile carriers.
- **The application service provider role**. Many new services will appear in the 3G and beyond generations of wireless networks, and the mobile carriers are potential providers of these new services, which may constitute a significant portion of revenue.
- **The content provider role**. Mimicking the fixed Internet, mobile carriers will also have to prepare content for their portals.

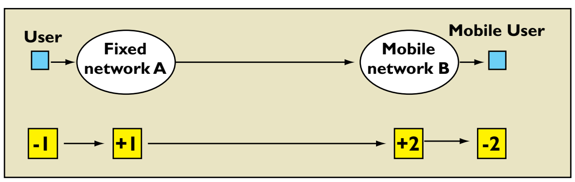

Figure 2. The receiving party pays for usage of the mobile network.

Because the cost of the equipment for the rollout of new services is estimated to be two to four times more than the cost of 2G equipment, a reduced number of carriers is likely to characterize each market. This number is estimated between two and four carriers for each country's market—it has been proved through game theory that the maximum number of carriers that does not impede profitability is four [4].

Carriers associated with telecom operators, especially for data services, will have a relative advantage because in most cases consumers appear to prefer bundled products. Changing traffic patterns are another factor affecting mobile carriers. Increased intra-country mobility, especially within the European Union where a common standard—GSM—is used, increases traffic related to roaming between countries. In some small countries, it is probable that traffic due to roaming will constitute more than half of the exchanged traffic.

Wireless Data Forecast

A somewhat similar situation with that of the early phases of the Internet characterizes today's wireless data scene: low data rates, abbreviated user interfaces, such as those of the Short Message Service (SMS) and the Wireless Application Protocol (WAP), text-centric output, and low-resolution graphics. As the capabilities of wireless networks to deliver data as well as the number of subscribers rise, growth similar to that of the fixed Internet will occur for the wireless Internet as well. The growth in the number of wireless subscribers and data use is becoming evident in recent years (see www.wow-com.com). In addition, data applications, albeit in the primitive form of text messages, are experiencing a similar increase: according to studies, one billion text messages were being exchanged in Europe alone over the wireless medium (see www.sims.berkeley.edu/research/projects/how-much-info-2003/telecom.htm). When carriers deploy higher-speed networks, the usability of wireless Internet will become much more obvious due to the use of data-rich applications. The iMode system in Japan is one example, which we will briefly review here.

A number of capacity-demanding data applications are expected to increase wireless data traffic [5, 6], including video telephony and videoconferencing, Internet browsing, mobile commerce, multimedia messaging and geolocation applications.

Wireless Internet Success Case Study: iMode. Although in its relatively early stages, the wireless Internet already has shown signs of its potential. A good example is the success of NTT DoCoMo's iMode system in Japan that enables users to access Internet services via their cell phones. The iMode system had 29 million subscribers by 2002, increasing by approximately 37,000 subscribers per day (see pressreleasenetwork. com/pr-2002/jan/mainpr1020.htm). The success of iMode has helped DoCoMo to become one of the largest mobile phone carriers worldwide. The iMode system is about to penetrate other markets as well, such as those of Germany, Netherlands, and Spain.

Technological Alternatives and their Economics. There exist a number of candidate technologies for offering data transfer in wireless networks, including: cdma2000, High Data Rate (HDR), Wideband CDMA (WCDMA), and General Packet Radio Service (GPRS). In [6], based on a cost-per-megabyte scenario, it is estimated that CDMA-based technologies have an economic advantage over GPRS due to the limited capacity of the latter. From the CDMA-based technologies, HDR is the most advantageous alternative for supporting data traffic, as it has a two- to three-times cost advantage over cdma2000 1X and WCDMA. This advantage of HDR is due to its optimization for data traffic.

Charging Issues

Mobility Charges. In most cases the price for placing a call through a mobile carrier is significantly higher than that through a fixed telephone carrier. This is because mobile carriers have paid a significant amount of money to acquire spectrum licenses and frequently spend large amounts of money installing new infrastructures. The actual price for a mobile telephone call is not constant but rather depends on factors including the policy of the carrier, the time at which the call is placed, or the user's contract. However, despite the fact that mobile calls cost more than fixed ones, these prices generally follow a declining rate due to the competition between carriers and the concerted effort to make mobile telephony a direct competitor of the traditional fixed telephone carrier.

Another interesting issue regarding the charges for the case of a user who places a call that ends at the network of a mobile carrier. In this situation, there are two approaches:

- *Calling Party Pays (CPP)*. This approach, shown in Figure 1, is mostly used in European countries. The caller pays for usage of both the fixed and the mobile networks. Thus, calling a mobile phone from a fixed one is more expensive than a call placed between two fixed telephones. In order to provide fairness to the callers, mobile numbers are preceded by special codes, which let the caller know that the charge for such a call will be higher than that for a call to a fixed telephone.
- *Receiving (called) Party Pays (RPP)*. This approach, shown in Figure 2, is mostly used in the U.S. and Canada. The called party pays for usage of the mobile network. Thus, calling a mobile phone from a fixed phone costs the calling party the same amount of money as when the call is placed between two fixed telephones. This approach is driven by the fact that in the U.S. consumers are accustomed to the situation in which local calls are free, thus paying for a call to a mobile phone in the same area would seem incongruous.

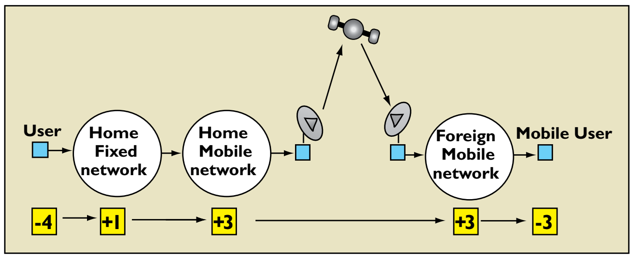

Figure 3. Charges for a call placed to a roaming user.

Roaming Charges. Figure 3 shows the case of a call placed from a fixed telephone to a user of a mobile carrier, who has moved to the operating area of mobile carrier located in a different country. This situation is known as roaming and imposes relatively high charges to the receiving party. As shown in the figure, an RPP/CPP combination is in effect in roaming situations. This is because it would be unfair to charge the caller for usage of the foreign mobile network since he or she has no way of knowing the called party is roaming to a foreign network. Thus, the cost of the call for the calling party is just the sum of the cost of using the fixed network and the cost of using the home mobile network, meaning the charge for the calling party is what it would be if the called party wasn't roaming. The extra cost of using the foreign mobile network is charged to the called party. This charge is usually much higher than the amount of money is charged to customers of the foreign network, a fact that may make roaming an expensive service.

Billing: Contracts vs. Pre-paid Time. Once the charges for utilizing network resources are summed up, mobile carriers must bill their customers. There exist two main approaches here: contracts and pre-paid billing. A contract is essentially leasing of a connection to the network of the carrier. Users that sign such contracts usually get the mobile handset for free. The mobile operators of course eventually get back the cost of the handset, since the contract forces users to pay a monthly rental charge for their connection irrespective of the fact that they might not use the connection at all. Of course the user is also charged for both calls.

Contracts have the disadvantage of limiting the user to a specific carrier for a certain amount of time. Thus, another approach appeared; that of "pre-paid" time. This approach, first applied by Telecom Portugal (TMN) in 1995, requires users pay in advance for both their handsets and the calls they make. Handsets can be bought from electronics stores and usually include a certain amount of credits, which translate into speaking time (and obviously credits for using other network services, such as SMS). Once the user of the phone has exhausted all the credits, the phone can be recharged via a simple procedure. The pre-paid approach has found wide acceptance in Europe and developing countries [1].

Charging Methods. Here, we describe some methods for charging in mobile networks [2, 3, 7]. Most of these methods have already been proposed for the Internet, but are equally applicable to mobile networks.

Metered Charging. The model charges the subscriber with a monthly fee irrespective of the time spent using the network services. However, most of the time this fee also includes some "free" time of network use. When users have spent this time, they are charged for the extra time using the network. This method is used in 2G networks for charging voice traffic. The way to charge voice calls is quite straightforward: The duration of the call is proportional to the call's cost. Nevertheless, sometimes charges decrease for increased network usage. Metered charging is well suited to voice calls, which are typically circuit-switched, since the user pays for the period of time the circuit is used. Furthermore, it adds little network overhead and is transparent to customers since it does not require configuration in their devices. However, this model is not suitable for charging the data services expected to be offered by the wireless Internet.

Packet Charging. This method is used for charging in packet-switching networks. It is more suitable for data than metered charging. This is because the user is not charged based on time but rather on the number of packets exchanged with the network. Thus, this method obviously calls for a system able to efficiently count the number of packets belonging to a specific user and produce bills based on these measurements. The disadvantage of packet charging is the fact that its implementation might be difficult and thus costly, since the cost of counting packets for each user might increase the complexity to the network. However, the overhead to subscribers remains minimal as the method is transparent to them.

Expected Capacity Charging. This method involves an agreement between the user and the carrier regarding the amount of network capacity that will be received by the user in case of network congestion; and a charge for that level of service. However, users are not necessarily restricted to the agreed capacity. In cases of low network congestion, a user might receive a higher capacity than the agreed one without additional charge. Nevertheless, the network monitors each user's excess traffic and when congestion is experienced, this traffic is either rejected or charged for. The advantage of this method is that it enables mobile carriers to achieve more stable long-term capacity planning for their networks. Expected capacity charging is less complex than packet charging both in terms of network and subscriber overhead.

Paris-Metro Charging. In this method, the network provides different traffic classes, with each class being characterized by different capabilities (such as capacity) and hence a different charge. Thus, users can assign traffic classes to their different applications based on the desired performance/cost ratio. Switching between traffic classes might also be initiated by the network itself in order to provide self-adaptivity. Paris-Metro charging is useful for providing network traffic prioritization in wireless data networks. Another advantage of the method is that it provides customers with the ability to control the cost of their network connections. The disadvantages of this method are an increase in the mathematical complexity of the network's behavior and thus cost of implementation and the fact that users must be familiar with the process of assigning traffic classes to their connections, which introduces some overhead for them.

Content-based Charging. A different approach to the problem of how to charge a customer for utilizing the network is content-based charging. The novelty of this approach is that users are not charged based on usage, but rather on the type of content they access.

Conclusion

Wireless networks constitute an important part of the telecommunications market. The wireless Internet is expected to significantly increase the demand for wireless data services and provide an important new revenue source for wireless telecommunication companies. **C**

References

1. Beaubrun, R. and Pierre, S. Technological developments and socio-economic issues of wireless mobile communications. *Telematics and Informatics 18* (2001), 143–158.
2. Cushnie, J., Hutchison, D. and Oliver, H. Evolution of Charging and Billing Models for GSM and Future Mobile Internet Services. In Proceedings of QofIS 2000 Symposium (Berlin-Germany, Sept. 2000), 313–323.
3. Franzen, H. *Charging and Pricing in Multi-Service Wireless Networks*. Master Thesis, Department of Microelectronics and Information Technology Royal Institute of Technology of Sweden, 2001.
4. Hugh, M.A., Down, K., Clements, J. and McCarron, M. *Global Wireless Industry Report: Part 1: The Changing Economics of the Wireless Industry*; www.totaltele.com/whitepaper/docs/wireless111600.pdf.
5. Nicopolitidis, P., Papadimitriou, G.I., Obaidat, M.S. and Pomportsis, A.S. Third generation and beyond wireless systems. *Commun. ACM 46*, 8 (Aug. 2003), 120–124.
6. *The Economics of Wireless Mobile Data*. Qualcomm whitepaper; www.qualcomm.com/main/whitepapers/WirelessMobileData.pdf.
7. *Value-Based Billing for Wireless Internet Services, Portal Overview*; www.asiatele.com/internet/wireless.pdf.

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