Best Effort versus Spectrum Markets: Wideband and Wi-Fi versus 3G MVNOs?

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Abstract

This paper asks is whether (i) 3rd generation wireless services, as embodied in the planned and soon to be offered services emerging first in Asia and Europe, or (ii) the unlicensed wireless services such as 802.11 or wi-fi but also including more advanced wideband and ultrawideband (UWB) services which are being experimented with primarily in North America, offer more compelling visions for advanced wireless services. we conclude that secondary spectrum markets are important for the viability of the 3G industry, and not only for reasons of efficiency. One large difference between 2G and 3G networks, observed in our models, was that voice services alone would not generate sufficient revenues for a 3G system. License holders which up to now have concentrated on selling a single product, will need to develop a much larger range of advanced applications, which will have to be marketed and packaged in different ways for different market segments.

Introduction

This paper compares two models for delivering broadband wireless services: best effort vs. QoS (Quality of Service) guaranteed services, such as traditional landline telephony, as well as cellular telephone services. We further focus on the differing ‘market’ versus ‘engineering’ philosophies implicit in alternative wireless service architectures - and visions for the future. We apologize up front for the acronym-laden discussion in this chapter. But given the chapter's focus on new technologies and standards, we must name names - even when those name are rather geeky.

But why focus on 3G (3rd Generation Cellular) and WiFi, also known as 802.11? For that matter, why care about wireless Internet access? First, these two technologies have seen rapid growth in investment on the one hand (3G) and deployment on the other (WiFi). Second, our focus on these technologies is derived from our interest in exploring the relationship between technologies and potential industry structures for wireless service provision. 3G, the preferred global next-generation solution of the dominant vertically integrated wireless service providers and WiFi, an alternative wireless local area network technology that could support a decentralized, end-user centric approach to service provisioning, span the range of alternative future wireless industry structures.

The question this chapter asks is whether (i) 3rd generation wireless services, as embodied in the planned and soon to be offered services emerging first in Asia and Europe, or (ii) the unlicensed wireless services such as 802.11 or wi-fi but also including more advanced wideband and ultrawideband (UWB) services which are being experimented with primarily in North America, offer more compelling visions for advanced wireless services. The visions are empirically tested in part through a cost model of a mobile virtual network operator seeking to operate in Europe. For advanced unlicensed wireless services such as wideband, the chapter can only speculate as to the costs at this point in time. Wideband is still under development through among other things U.S. Defense Advanced Research Project Agency initiatives, and is not yet available for commercial services. Nonetheless, hopefully the speculation and contrast with the (soon-to-be) known realities of 3G services will help highlight emerging cost and policy issues, and forewarn industry, governments, and entrepreneurs of challenges they must soon confront - if they do not feel threatened enough already by the challenge of recovering their hefty investment in 3G, at a time when users are gravitating toward 802.11.

First, the chapter reviews the alternative wireless technologies in question. Then a cost model is developed to explore the viability of a Virtual Mobile Network Operator in Europe. The European market was selected for analysis because of the high level of demand for wireless services there, and the relative maturity of its secondary spectrum market mechanisms in specific cases. The chapter then offers conclusions and policy recommendations to accelerate development of new technology to provide viable alternatives for packing more uses and users in the same wireless space, on a ‘best effort’ and/or market basis.

3G (Third Generation Mobile) versus 802.11 and Wideband Systems: A Comparison

3G ands wi-fi technologies have fundamental technical differences, due to the different design objectives of their developers. 3G stresses ubiquitous coverage and continuous mobility, which is a trade off against the severe limitations on available bandwidth that it endures. However, instead of the reputed data rate of 2MBps, ISDN-level data rates on the order of a few hundred kbps are the best that is expected from 3G. 802.11b offers 10Mbps but potentially only in local hotspots because the coverage range is so limited (roughly 300 feet – the typical cell diameter for 3G is much larger). In addition, the technology to do cell hand-off for 802.11b has not yet developed to the same extent as in 3G and second generation cellular networks. The wider-area capabilities being developed in wideband and ultra-wideband systems will also be highlighted below, after first defining our terms more precisely.

1. 3G

3G operators are required to have a license. This gives them exclusive property rights to the spectrum, which makes it feasible for them to support QoS guarantees that are essential for the commercial viability of services such as telephony and data—although for data, QoS may be more flexibly construed. In essence, the spectrum management paradigm gives the licensee a right not to be interfered with when transmitting in its licensed spectrum allocation.

Restrictions on licenses help facilitate the enforcement of these property rights. They define the services to be offered and the types of devices to be used, among other things, which helps assure the licensee that it will be able to operate without molestation in the licensed bandwidth for tasks for which license was granted. Where exclusive ownership exists, it is easy to determine who is at fault when interference is an issue.

2. (Ultra)Wideband

The advantages of distributed systems are illustrated by the growth of the Internet. The rapidly falling cost of computation makes it cost-effective to spread intelligence throughout a system. In general, distributed platforms offer increased fault tolerance, cover a greater geographic area, and support enhanced resolution coverage. (DARPA, 2001)

Ultra Wideband (UWB) radios, also known as "carrier-free" or "impulse" radios, are characterized by transmission and reception of short bursts of radio frequency (RF) energy (typically on the order of fractions of nanoseconds in duration) and by the resultant broad spectral bandwidth. (DARPA, 2001) Such systems may operate at a relatively low power level compared to conventional systems. Wideband and UWB may offer potential advantages such as: immunity to multi-path cancellation, low probability of detection with low energy density transmissions, enhanced penetration capability with the presence of low frequency spectral content, and minimized hardware complexity. (DARPA, 2001) UWB radios may also take advantage of the capabilities being developed for software radios to offer a wide variety of software-controllable parameters to create highly resilient and scalable networks. (Vanu, 2001)

The promised potency of decentralized system intelligence, however, cannot be realized without a robust interconnection network tying the nodes together. Coordinating the assignment of available spectrum. The problem of spectral allocation is compounded by the trend of decreasing domestic military bandwidths and by the inconsistencies of the international spectrum allocation environments. based on ultra-wideband (UWB) radios and to exploit its unique physical layer properties to form robust, scalable networks.

3. 802.11b (Wi-Fi)

Wideband and Ultrawideband systems are of interest to researchers and the military, but are of unproven commercial viability. Wireless local area networks, relying on less sophisticated technology but built around similiar design principles for spectrum sharing and best effort services are already deployed by businesses and hobbyists alike in a wide variety of settings. Many of these rely on the 802.11 family of standards.

802.11b wireless services use shared, unlicensed spectrum and therefore do not grant operators exclusive property rights to spectrum. The interference paradigm associated with operating on an unlicensed basis, requires all users to tolerate background noise, and limits each user's contribution to this background noise (chiefly via power limits). With more users, more congestion and more interference, this conflicts with ability to offer QoS guarantees.

In what ways are WiFi and 3G similar? First, one could ask about which problem each of these technologies solves, and in what sense these problems are comparable. Both are wireless, which facilitates mobility—broadly construed as the ability to move devices around without having to move cables and furniture. However, 3G is about real mobility (staying connected while traveling in a car across large geographic distances); whereas 802.11b is about local connectivity (conceived as one-cell technology).

Both are access or edge-network technologies, which means they are alternatives for the last-mile. Beyond the last-mile, both rely on similar network connections. For 3G, this constitutes wireless access to the cell base station, and then a dedicated landline connection to the carrier's router. For 802.11b, this means wireless connectivity to the base station, and then perhaps shared wireline or dedicated wireline service to ISP hub. Finally, both offer broadband data service, which can be broadly defined as "faster than what we had before and with potential for 'always on'." The 3G operator's bandwidth is much more limited than that for an 802.11 operator, except in the unlikely situation where it is used in a fixed wireless mode, which is beyond the scope of this chapter.

How are the two technologies different? This question can be answered most readily by looking at their current business models and deployment strategies. 3G is an extension of the cellular service provider model, which upgrades existing 2G digital mobile voice infrastructure to 3G digital infrastructure and is capable of delivering voice and data services at speeds ranging from 144kbps to 2Mbps (with the latter option only feasibly in fixed mobile applications). 802.11b, by contrast, is an extension of the Ethernet-family of 10Mbps LAN technologies to wireless networks supporting wireless connections at distances up to 300 feet. 3G will require the purchase of additional customer equipment, whereas 802.11b might piggyback on the business deployment of WLANs (Wireless Local Area Networks).

The status of technology development is also quite different. 3G is still projected (the first actual 3G service was started in Japan by DoCoMo in October 2001), while 802.11b is real and emerging. There are lots of business and, increasingly, home wireless LANs currently using the latter technology, with some pay-for-use services (Mobilstar) currently in operation, and roll-outs for more underway (Starbucks). 3G is based on an international standards effort to provide a smooth evolution from existing 2G digital mobile wireless technologies, and includes technologies such as WCDMA, CDMA 2000, and UMTS. The guidelines are specified by the ITU in its IMT-2000 report.

Although the standards picture is clearer in the 3G realm, there is some confusion about which technologies will be adopted in different parts of world. Chaos is greatest in the US, where there is less harmony among existing 2G infrastructure, while 802.11b is a specified standard from the IEEE (part of the evolving Ethernet family of standards) and is already incorporated in mass-market products. Although interoperability among 802.11b devices is assured, there are compatibility and co-existence issues associated with 802.11b, which is broadly thought of as one many in the class of WLAN technologies which includes HomeRF and BlueTooth.

3G is more developed than its unlicensed counterpart as a business and service model. It represents an extension of existing service provider offerings into new services, but does not represent a radical departure from underlying industry structure. The upstream equipment supplier markets, and ultimate consumer demand are undeveloped and unproven with 3G, though this may not be true either, as the identity of likely equipment manufacturers is well-known.

802.11b is more developed from the perspective of upstream supplier markets of equipment for WLANs. However, the commercialization of 802.11b as a platform for commercial services is largely untried. 3G access devices will include mobile phones, PDAs, and other devices for which power may be more of an issue. However, PCMIA cards will also support wireless PC access. 802.11b first in PC's but also extending to same types of devices as 3G.

Spectrum policy and management will, of course, be one of the most critical factors in determining the success or failure of the technologies in question. The contrast here is stark: 3G uses licensed spectrum; 802.11b uses shared spectrum. This has important implications for (i) cost of service, (ii) QoS and congestion management, and (iii) industry structure. These differences are graphically summarized in Table 1 below.

Table 1 -- Where is the Wireless Grid Going to Come From?

Best Effort/Unlicensed Nomadic Spectrum Market-Based Mobile

Wide-Area Shared Spectrum	Local Area Shared Spectrum	Licensed/Bought Spectrum	Secondary Spectrum Market	Service Level Agreement/e-services Trading
(ultra)Wideband	Wi-Fi/802.11	2G (bundled)	3G MVNOs	4G (?)

Secondary Spectrum Markets:

A Model of Business and Regulatory Challenges

The European Community has begun to develop and implement several comprehensive plans for effectively managing spectrum, based on the increased demand for new services. It has recognized that the best way to realize the maximum benefits from radio spectrum is to permit and promote the operation of market forces in determining how spectrum is used. A principal tenet of this market-based approach is that in order for competition to bring to consumers the highest valued services in the most efficient manner, competing users of spectrum need flexibility to respond to market forces and demands.

One suggested method for increasing the efficiency of spectrum use and providing the much-needed flexibility, is through the development of secondary markets. With a functioning system of secondary markets, licensees would be able to trade unused spectrum capacity, either by leasing it on a long term basis (if their own infrastructure is not yet developed) or by selling spare capacity during off-peak periods.
The resulting efficiency gains would effectively increase the amount of spectrum available for users. This would allow for the development of new services and technologies that would otherwise not be available, increasing competition in the marketplace. In addition, as licensees adopt newer digital technologies, they are likely to become more efficient and have additional capacity that can be sold in secondary markets. Facilitating the leasing of spectrum would introduce economic incentives to develop efficient technologies, as licensees will be able to sell spectrum freed by the efficiency gains. The presence of secondary markets makes it more profitable for licensees to be spectrum efficient.

Although there is a general scarcity of spectrum, existing allocations of spectrum are not always used efficiently.[i] Unavoidable factors include limitations in technology, or perhaps just the nature of the band itself (for example, we would not expect police bands to be continuously transmitting high bit-rate data). But there are also less immutable reasons for low spectrum efficiency. Existing licensees may not be fully utilizing the spectrum that has been assigned to them for some of the following reasons[ii]:

A licensee's business plan, even when taking future growth into consideration, may not encompass some portion of its assigned frequencies or geographic service area. In establishing a new service, a licensee may not need to use its entire spectrum allocation for a period of several years as it grows its customer and operating base. A licensee may also initially face problems in equipment availability, which will (of course) affect its ability to rapidly build out services, as the equipment manufacturers may look for a clear indication that the nascent communications business will support equipment orders. Holding unused spectrum in such circumstances may serve legitimate business needs, though it could leave a substantial amount of spectrum, especially in rural areas, lying unnecessarily fallow, while new services and data networks are unable to acquire spectrum of their own.

Secondary markets could improve performance under both of these scenarios. For 3G, secondary markets could allow more flexible management of property rights which could in the dynamic reallocation of spectrum rights to its most efficient and optimal use. For 802.11b, by contrast, secondary markets could create property rights that are needed to manage QoS. As soon as congestion becomes an issue, the question becomes how to allocate scarce bandwidth—that is likely to mean that need exclusivity. Noam of has argued in favor of no property rights and shared access, relying instead on as-yet-unspecified sharing protocols to solve the allocation problem. Hazlett has argued quite strenuously in favor of property rights, noting that sharing protocols—when and if available—could easily be compatible with a property rights regime. However, Hazlett argues in favor of property rights and markets as a superior alternative to shared spectrum and, presumably, the public enforcement of road rules.

The technical foment demonstrated by the vibrancy of 802.11b, and the market experiments that may be failing with HomeRF, BlueTooth, LMDS, and other wireless technologies that have seen ups and downs in the marketplace, however, points to need for the ability to more flexibly reallocate spectrum across technologies, and to be agnostic (as policymakers) about what wireless technology will be best in last mile.

Finally, secondary markets or license flexibility, may be useful in developing integrated approaches that might link both technologies (for example, integrated services that uses 3G for control channel and 802.11b for high speed file transfer when available).

Table 2-- Regulatory Issues in Secondary Spectrum Markets

The core elements for an efficient spectrum market are[1]:

- A large number of buyers and sellers to create competition necessary for an efficient market
- Clearly defined rights to the spectrum for both buyers and sellers
- Free entry and exit to the secondary markets
- Fungibility of spectrum
- Availability of relevant information to all buyers and sellers
- A mechanism to bring buyers and seller together and facilitate the transaction with reasonable administrative costs and time delay.

(Source, FCC, 2000)

Some of the policies being suggested being suggested / implemented to address these elements are discussed below. The first three elements are closely correlated. There are few parties willing to sell spectrum. Licensees are reluctant to participate in this market because the following issues have not been adequately answered by current regulations. If they lease or resell their unused spectrum, will the government be able to reclaim that spectrum? If they wish to reclaim their spectrum from the buyer but the buyer does not agree, what are the rules? Potential buyers have their own concerns as well. Spectrum can have a major effect on competition. If there were no sellers, would regulators force licensees to offer fallow spectrum for sale? After substantial investment in a network, do buyers have any protection from sellers suddenly reclaiming the spectrum? These are issues that need to be addressed before firms will participate in a secondary spectrum market. An ideal secondary market should be timely, nondiscriminatory, transparent, with carefully crafted rules for license transfers. [iii]

To increase the fungibility spectrum, regulators or businesses may need to standardize spectrum trading contracts to some extent. Possible attributes include Quality of Service (QOS), bandwidth, frequency bands and time blocks. A new technology that promises to improve the fungibility of spectrum is the "software defined" radio, which would enable devices to use different frequency bands flexibly. Buyers can buy spectrum of any frequency, letting the communications device adjust the frequency used as needed.

To minimize the administrative costs and processing time, modification of certain regulations will be necessary. For one, the requirement for licensees to be responsible for all content on their frequency bands, which would imply even the content of the party they are leasing the bands to, needs to be changed. The requirement for every lease transaction to have the approval of the regulatory body is another impediment to secondary markets. Spectrum has always been a closely regulated resource, and changes are needed to ease some of the regulations.

In Europe, spectrum trading does exist in a limited form. In these transactions, licenses are transferred from one party to another in exchange for some form of consideration as a result of a contract. Spectrum lease or resale contracts are private contracts negotiated by sellers and buyers with very specific agreements on frequency band, time period, and service area. These highly customized contracts have little fungibility and cannot be traded between multiple parties. Buyers and sellers generally contact each other directly, or might use the services of a broker who has the necessary industry knowledge.

3G comes from the cellular world where focus is on a model of service providers who own the infrastructure (including the spectrum) and sell service on that infrastructure. For customers, 3G is operating expense. It is close to the wireline telephone business. Mindset is on long-lived capital assets, ubiquitous coverage, and service integration. 3G is perceived to be an end-to-end service, but wireless link is the access link.

802.11b comes out of the LAN industry which is by-product of computer industry. Focus is on equipment makers who sell boxes to consumers. Services are free. For consumers boxes are an asset. 802.11b can be used as an access link, but has not heretofore been thought of as an end-to-end service.

1. Capacity Constraints

To what extent will these services threaten those of 3G license holders in Europe? What kind of pressure will existing 3G and 2G operators put on regulators to limit the services offered in the unlicensed bands. It is imperative that license holders fill their networks with traffic as quickly as possible to start earning a return on their investments. Selling exclusively voice services, as in 2G networks, will not be profitable in 3G networks. As mentioned earlier, revenue in these networks will come from providing the higher value data services that are made possible by the technology.

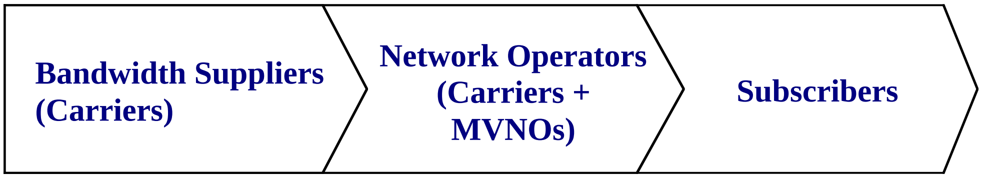
2. Secondary Spectrum Market Pricing Model for Mobile Virtual Network Operators (MVNOs)

License holders, which have historically concentrated on selling a single voice product, will now need to develop, market, and package a much larger range of advanced applications.[iv] Offering the full range of mobile commerce, entertainment, banking, shopping, information, and other services from which the majority of 3G revenues will come, will require very different sets of skills and expertise. In order to meet this demand, access these markets, and maximize their 3G revenues, license holders may have a strong incentive to lease parts of their spectrum wholesale to value-added resellers called Mobile Virtual Network Operators (MVNOs), which can serve these specific market segments more efficiently and profitably than the license holders themselves.

MVNOs can be defined in a variety of ways based on technical and marketing-based factors. The Yankee Group, for example, classifies MVNOs as service operators that (i) do not own their own spectrum, and (ii) have no radio transport infrastructure. MVNOs do, however, have complete control over (iii) their SIM cards, (iv) branding, (v) marketing and promotion, (vi) billing, and (vii) all customer-facing services.[v] Ovum similarly defines an MVNO as “a network operator in a GSM environment that provides its own SIM card, or, in a non-GSM network, an entity that creates a unique subscriber ID.”[vi] To date, however, MVNOs have settled for adopting a mere branding approach, just to get into the game. This may continue. The future for MVNOs, according to one analyst, is “brand, service, customer base, (and a) sophisticated billing system.”[vii]

An important feature of MVNOs, is that customers are unable to tell the difference between the virtual operator and the host-network operator in terms of network performance and service. The MVNO adds value by usually having a strong brand name, and understanding its potential customer base better than the host network operator itself. This allows the MVNO to target specific customer segments, and to ‘repackage’ the services of an existing network operator for that segment. The MVNO buys managed network capacity from the host network operator, and presents itself to customers as a fully fledged operator.” MVNOs are distinguished from mere service providers as the former typically handle its own billing, while the latter simply resell bulk airtime from the operator.”[viii]

Figure 1-- The Mobile Service Industry Value Chain



The original aim of the secondary sprectum market model was to obtain an estimate for the price of 3G spectrum in secondary markets in Europe. Examining a value chain for the provision of mobile services, the firms in the industry can be divided by their functional roles into two categories, bandwidth suppliers and mobile network operators. Bandwidth suppliers control the infrastructure of mobile services. They own the licenses to the spectrum and operate the cell sites. Traditional carriers such as AT&T fall under this category. Mobile network operators (MNOs) provide the content and services, both voice and data, to subscribers. Traditional carriers generally provide voice services and they fall into this category. Mobile Virtual Network Operators (MVNOs), such as Virgin Mobile, have neither spectrum nor infrastructure of their own, but provide mobile services through leasing agreements with carriers, and are MNOs as well.

In a secondary spectrum market, bandwidth suppliers would lease the spectrum they own to the MNOs. The price of spectrum would be the price which bandwidth suppliers sell spectrum to MNOs for. Even for traditional carriers (which span both categories), there would presumably be transfer pricing between the infrastructure division and their mobile services division[ix].

We constructed two different models to determine the range, which prices may take.[x] For simplicity, we refer to bandwidth suppliers as carriers. In the carrier model, the various costs of carriers are used to find the effective cost of supplying spectrum. The MNO model looks at both revenues and costs, to find the maximum price MNOs can pay for spectrum. These two models provide a lower and higher bound for market prices.

The models focus on the countries in the European Union, in particular those that have already issued 3G licenses[xi]. Spectrum licenses can be a major cost component for carriers, and varies widely from country to country. For example, Sweden issued its 3G licenses for only a nominal registration fee, while Germany’s 3G auctions raised $46.2 billion. Licensing costs are too large to ignore and too different to predict, hence only countries that have completed their licensing process were considered in the model. The dominant technology in Europe is W-CDMA and almost all carriers will be using this form of 3G technology. Costs used in the model were based upon a W-CDMA architecture.

The models make no assumptions on how spectrum will be traded, although they assume that spectrum can be traded without cost. Although this will not be likely (or will at least require a highly developed secondary market), the nascent secondary spectrum markets in

Europe do not allow an accurate estimation of costs. As a simplification, the price of spectrum has been assumed to be constant over time. Dynamic pricing may be more accurate, but it is difficult to take into account the losses firms have to bear in the first few years. Static pricing only holds when the relationship between demand and supply is constant, i.e. that carriers are predicting spectrum demand with high accuracy, and are building infrastructure based on these predictions.

3. Carrier Model Methodology

The aim of the carrier cost model is to determine the cost of supplying spectrum. Specifically, it calculates the minimum cost per Mbyte the carrier has to charge to recoup its investment over a ten-year period[xii], under a specified profit margin. This provides a lower bound for spectrum prices in secondary markets, below which carriers would be operating at a loss. It does not determine an actual market price, since carriers could charge higher prices depending on market demand.

The model starts with the basic profit equation, where

Profits = Revenues - Costs

Revenues = Gross Margin * Costs
= Gross Margin * [Infrastructure Costs + Operating Expenses + Spectrum Licensing Costs]

Since the carriers are defined with spectrum sales as their only source of revenue, the equation can be expressed as

Q * P = Gross Margin * [Infrastructure Costs + Operating Expenses + Spectrum Licensing Costs]

P = Gross Margin * [Infrastructure Costs + Operating Expenses + Spectrum Licensing Costs] / Q

Where Q is the quantity of spectrum sold (measured in Mbytes) and P is price per Mbyte (measured in U.S. Dollars). Each of the terms is described below.

P: This is the price per Mbyte, expressed in U.S. dollars that the carrier has to charge to recoup its costs and meet a specified gross margin target. This value is calculated by the model and is assumed to be constant over time.

Gross Margin: This represents the profit target of the carriers, expressed as a percentage. It is a constant specified in the model.

Infrastructure Costs: This is the cost of constructing network infrastructure, after amortization. The infrastructure required is based upon projected subscriber numbers[xiii] and cell buildout. Component costs were assumed to decrease by 10% each year. Capital costs are amortized at 6%[xiv]. The cost is expressed in Net Present Value (NPV) form.

Operating Expenses: Operating expenses for carriers can be divided into two categories, cell maintenance and general operating expenses. Cell maintenance expenses are based upon the number of cell sites, while general operating expenses were calculated in terms of subscribers. Due to difficulty in obtaining operating expenses for specific items, which generally falls under proprietary information, an aggregate general operating expense per subscriber was used instead. Data was obtained from publicly available industry information. The expense is expressed in NPV form.

Spectrum Licensing Costs: This is the price that carriers have paid to obtain 3G licenses in Europe. The information is publicly available from government websites.

Q: This is weighted sum of data traffic sold from 2001 to 2010. A weighted sum was used to measure Q in a magnitude equivalent to the other terms of the equation (which are in NPV form).

Subscribers: Subscriber projections up to 2004 were obtained from Forrester Research[xv]. Detailed projections for individual countries after 2004 were not available, but were instead extrapolated from UMTS-Forum reports.

Cell Buildout: Under the 3G licensing process in Europe, carriers generally had to agree to provide mobile coverage to a pre-specified percentage of the population, within a certain period of time. Cell construction was assumed to be linear, reaching the required coverage in the time limit. There was also an assumption that all urban areas would be covered before rural areas. Data was obtained from public sources.

- Cost of supplying spectrum

In the interests of space the full mobile network operator model is not presented here, it can be found at www.murrow.org. But conclusions from the model, which are relevant to the present chapter, are highlighted here, the cost of supplying spectrum in relation to the amount of spectrum sold was found by varying the number of cell sites built. As cell sites increase, system capacity increases while fixed costs such as spectrum licenses remain unchanged. This is analogous to carriers increasing cell site density to ensure sufficient capacity for users.

Two scenarios were studied. Under the base scenario, carriers would only provide coverage as required by their national regulatory authority, and each carrier would construct their own cell sites. Total system information capacity was assumed be 668 Mbps / MHz / Cell, which was the maximum data rate of the system.

In the “Most Likely” scenario, where national buildout requirements were low, it was assumed that carriers would nonetheless provide coverage for all urban areas (due to market demand). Carriers were also allowed to share their cell sites. Total system data capacity was reduced to 450 Mbps / MHz / Cell with the assumption that interference would reduce the maximum throughput.

The differences between the two scenarios are small. Although there are cost savings from cell site sharing, this is balanced by the lower system capacity available per cell site in the “Most Likely” scenario. The average difference in prices between the two curves was $0.02. Subsequent analysis was conducted using the “Most Likely” scenario.
In perspective, the voice traffic component will only amount to 78,000 million Mbytes over the next ten years. Projected subscriber demand for voice and data services will reach a level of 1,500,000 mil Mbytes over the next ten years, which indicates a cost of $0.17 per Mbyte.

♦ **Costs Components of Carriers**

Examining the costs for the carriers, the cost of spectrum licenses constitutes approximately 35% of a carrier’s total costs. Infrastructure costs are small (1% when amortized, 3.5% when not), with operating expenses being the bulk of a carrier’s expenses.

4. Sensitivity Analysis

A Sensitivity Analysis was conducted at the demand level projected by the MNO model.

♦ **Operating Expenses**

Operating expenses is the largest component of a carrier’s cost. Sensitivity analysis was done to identify how spectrum prices change with operating cost per subscriber.

♦ **Sensitivity to Cell Sharing**

The European Union has issued directive s[xvi] calling for the abolition of restrictions on infrastructure sharing. It is likely that within the next few years, cell sites will be shared between carriers, reducing infrastructure costs and increasing system capacity. Sensitivity analysis was conducted to observe the effects of cell site sharing.

From the combined pricing functions of carriers and MNOs, 3G mobile services will only become profitable if demand rises above 800,000 mil Mbytes within ten years. Since voice traffic will only constitute 78,000 mil Mbytes, there must be significant uptake of mobile data services for the 3G industry to recoup its costs. Fortunately, industry projections place mobile demand at 1,500,000 mil Mbytes. At this point, the price of spectrum will range from $0.17 per Mbyte to $0.39 per Mbyte.

One clear result from the model is that data traffic will be an important component of carriers’ revenues. Voice traffic will only constitute 8% of total traffic and cannot generate sufficient revenues to cover carriers’ costs on its own. This emphasizes the need for MVNOs. In 2G systems, traditional carriers were able to provide voice services, which formed the bulk of wireless traffic. In 3G systems, data services will be the mainstay of mobile traffic. Most carriers are not positioned to provide such services, and furthermore it seems practically impossible for a single firm to provide the plethora of data services needed to sustain a 3G network. MVNOs will be essential to the success of 3G systems.

The models also indicate that the 3G market remains profitable, despite the claims of German carriers that high license fees are driving them into bankruptcy. At the projected demand for data services, subscriber revenues are sufficient to cover the costs of carriers.

The German and British auctions were most likely overpriced, but as a whole, European licensing fees are still reasonable. Most of the licenses are owned by a handful of firms or consortiums. For example, Vodafone (either singly or operating within a consortium) has acquired 3G licenses in 6 out of the 10 European auctions / beauty contests. Forrester research predicts that consolidation will leave only five groups serving all mobile users in Europe by 2008. A company such as Vodafone would find the high prices paid in Britain offset by the low licensing fees of Sweden. Aggregated together, revenues are sufficient to cover the licensing fees paid in Europe.

5. Weakness of the 3G Models

The models only examined the countries that have completed their 3G licensing process. Some of the earlier auctions had licensing fees that would be reached today, and the general trend is towards lower licensing fees. A complete European model (when all national 3G licenses have been issued) should have lower costs than our predictions.

3G markets and regulations are in the midst of a revolution. Many of the 3G systems and services have never been used on a large scale before. Laws are changing as regulators try to facilitate the development of 3G, and market predictions are being modified month to month. Our models are able to accommodate dynamic changes in most variables, but it is difficult to factor in the changes when information about it is constantly changing. The model represents a static prediction, based on best information available at the time of writing. Probable changes to the regulatory environment include a lifting of restrictions on infrastructure sharing and the allocation of further blocks of spectrum by 2005.

Some implications for industry structure and public policy are briefly summarized here. We discuss emerging themes for wireless services and how do these differentially affect two technologies. The implications for the extent of horizontal and vertical integration are significant. 3G is vertically integrated whereas WiFi admits a decentralized approach. But, of course, this does not have to be case. WiFi could be integrated into a 3G model as a local hotspot capability.

Conclusion and Policy Recommendations

In the wired Internet premium services such as for example, content delivery networks offer forms of guaranteed services. On the other hand hundreds of millions of people rely on best effort email and instant messaging services. A similar wireless bifurcation and competition between service offerings relying on guaranteed services, and built therefore at least in part upon spectrum markets, and ‘best effort’ unlicensed services, is beginning to unfold. This competition for spectrum and customers is also a competition of visions, which will intensify in the years to come, as the costs and benefits of wideband services become better understood.

Moving from vision to empirically testable reality, we conclude that secondary spectrum markets are important for the viability of the 3G industry, and not only for reasons of efficiency. One large difference between 2G and 3G networks, observed in our models, was that voice services alone would not generate sufficient revenues for a 3G system. License holders which up to now have concentrated on selling a single product, will need to develop a much larger range of advanced applications, which will have to be marketed and packaged in different ways for different market segments. It will require very different sets of skills and expertise to offer the full range of mobile commerce, entertainment, banking, shopping, information, and other services from which the majority of 3G revenues will come. 3G networks must offer a broad range of data services, which traditional carriers are not positioned to do. Secondary spectrum markets allow carriers to leverage their strengths in network infrastructure while portioning out data services to firms able to serve customers better (and hence increase demand for mobile traffic).

In these secondary markets, our models predict the price of spectrum to be between $0.17 per Mbyte and $0.39 per Mbyte. The actual price will most likely fluctuate with supply and demand, although in the long run, competition should reduce prices towards the lower bound. We recognize that the 3G market in Europe is changing rapidly, and too many variables are uncertain. A rise or fall in auction prices next year, or the implementation of new European directives, could easily change spectrum prices. Our models espouse a methodology for valuing spectrum in secondary markets that needs to be recalibrated as new information becomes available.

The implications for spectrum policy of the wireless technologies addressed in this chapter are potentially the most important issue. Can best effort and guaranteed services coexist in the same bands? What incentives would be needed to induce and enable sharing – presuming as in the wired Internet, technical and operational efficiencies greater than their costs can be obtained through sharing technical resources – not including spectrum? Regulators and policymakers have just begun to consider such issues through for example formal rulemaking procedures of the United States Federal Communication Commission, and technical analyses undertaken by the U.S. Defense Advanced Resrach Projects Agency and National Telecommunications and Information Administration underway in 2001; below we offer a few suggestions for wireless policymakers, technologists, and business leaders to consider for the future.

Recommendation 1: Demand for mobile services will require new spectrum allocations. Especially where such allocations may be problematic, innovative approaches to spectrum use and sharing such as those described in this chapter should be explored.

Recommendation 2: 3G licensing processes should ensure competition in infrastructure provision whenever possible, while permitting in principle infrastructure sharing and enabling roaming between networks. The regulatory framework should not present barriers to infrastructure sharing arrangements if they do not have negative impact on competition between operators.

Recommendation 3: Policies and initiatives should encourage both supply and demand for spectrum usage rights and development of an efficient secondary market in such rights.

Recommendation 4: Large swaths of spectrum for 3G services may be unavailable in for example North America due to military needs. If new technology provides a viable alternative for packing more uses and users in the same space, on a 'best effort' basis, such a possibility should be explored as a high priority by researchers and policymakers alike.

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Endnotes

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[i] This chapter draws heavily upon the work done by co-author Raymond Linsenmayer and his colleagues in spring 2001 to develop pricing and cost models of European spectrum markets. In particular, this chapter draws upon the work of co-author Raymond Linsenmayer for his master's thesis. See Raymond Linsenmayer, *Secondary Spectrum Markets in Europe*, MALD thesis, Fletcher School of Law and Diplomacy, Tufts University, 2001. (www.murrow.org) In addition, the spectrum market model described in this chapter was first developed by Raymond Linsenmayer and his colleagues as a class project in spring 2001 to develop pricing and cost models of European spectrum markets. See Li Jiang, Yong Li, Raymond Linsenmayer, Shushain Colin Ong, *Wireless Spectrum Pricing in Secondary Markets,* Class Project for Professor Lee W. McKnight, ESD.127/DHP 232 *Telecommunications Modeling and Policy Analysis*, Fletcher School/ MIT, Spring 2001. (www.murrow.org).

[ii] *Public Forum*, FCC, May 31, 2000

[iii] Policy Statement, FCC, December 1, 2000, P19

[iv] As previously noted, much of this section is drawn from Jiang et. al, 2001.

[v] See *Mobile Virtual Network Operators: Can They Succeed in a Competitive Carrier Market?* The Yankee Group. 2000. p. 1

[vi] "The Virtual Network Space" By Paul Quigley." *Wireless Week.* September 4, 2000

[vii] See By Joanne Taafee. "Mobile Virtual Network Operators – Marking Out Their Territory" *Communications Week International*. March 5, 2001.

[viii] Jo Shields, "Energis Sees UK as a Test-Bed for Bigger Mobile Ambitions" *Mobile Communications.* March 6, 2001.

[ix] In competitive markets, the optimal transfer price should be equivalent to the market price.

[x] Jiang, et. al., op cit.

[xi] At time of writing, they are Austria, Belgium, Finland, Germany, Italy, Netherlands, Portugal, Spain, Sweden and U.K.

[xii] Most industry analysts use ten years as a benchmark before 3G technology becomes dated and needs to be replaced.

[xiii] Assumption that carriers will purchase equipment (AUCs, Billing Centers, etc.) to ensure that all users can be supported.

[xv] For more information see Forrester Research, "Europe's Mobile Internet Opens Up"

[xvi] See The 90/388/EEC Service Directive, the 96/2/EC Directive on mobile and personal communications, the 96/19/EC Full Competition Directive, and the European Parliament and Council Directive on Interconnection in Telecommunication with regard to ensuring Universal Service and Interoperability through application of the principles of Open Network Provision