Technology of Fixed Wireless Access

by David Trinkwon

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TECHNOLOGY OF FIXED WIRELESS ACCESS

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ABSTRACT

The ability of different wireless technologies to co-exist within a single geographic area, owned and operated by different service providers with relatively simple sharing arrangements for common infrastructure is one of the key aspects which makes wireless technology a valuable addition to the Universal Service concept - in fact it can change the fundamental assumptions embodied within traditional approaches to Universal Service.

This paper examines the challenge operators and regulators have in providing telecommunications services, especially to smaller communities, and the role Wireline Equivalent Fixed Wireless Access systems can play.

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BIOGRAPHY

David Trinkwon is responsible for developing the North American market for Nortel's Fixed Wireless Access (FWA) systems based on the Proximity* I technology developed in association with Ionica plc**. This system is currently being deployed for commercial "Wireline Equivalent" access networks in the UK, Finland, Czech Republic, Sri Lanka and Australia with further applications planned or committed throughout South America, Asia, the Far East, Canada and Europe during 1997 - 98.

David has more than thirty years of experience in the telecommunications industry, having worked throughout the world on a wide range of switching, transmission, access, customer premises and network management assignments during appointments with British Telecom, DSC Communications Corporation, Bell-Northern Research and Northern Telecom.

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** Ionica plc is the world's first licensed telecommunications operator with an access network based on wireline equivalent FWA. The service was launched on May 14, 1996 in the United Kingdom.

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INTRODUCTION

Fixed wireless access is the use of wireless technology to replace copper to connect subscribers to the telephone network. There are numerous acronyms for the use of wireless technology in local loop applications, as well as a variety of applications which require differences in the choice of wireless technology to optimize the economics, performance and spectrum utilization for each one.

The ability of different wireless technologies to co-exist within a single geographic area, owned and operated by different service providers (with relatively simple sharing arrangements for common infrastructure) is one of the key aspects which makes wireless technology a valuable addition to the Universal Service concept - in fact it can change the fundamental assumptions embodied within traditional approaches to Universal Service.

At the same time that new developments in wireless technology are providing more choices, regulators are in the process of redefining everything that is critical to local loop and access investment, for example :-

- Permitting the use of Cellular / PCS spectrum for Fixed Access
- Assignment of Spectrum for MMDS, LMDS and point-to-multipoint services
- Facilities Unbundling, Interconnection, Resale and Access Competition
- Access Charge reform
- Universal Service re-definition and subsidy reform.

There is a significant danger that these latter changes will be finalized around traditional (cabled) technology assumptions, without making full allowance for the new range of freedoms and choices enabled by wireless technology. This is therefore a timely opportunity to understand these issues within the context of Universal Service. I will concentrate on the technology and spectrum factors and in particular I will describe the new generation of Fixed Wireless Access (FWA) systems which are already being deployed in the rest of the world by three key North American vendors .

These technologies are currently not available in North America because suitable spectrum has not yet been made available by the regulators, and as such the industry's wireless focus is understandably centered around the PCS, Cellular, MMDS and LMDS applications. I believe that interest and support for FWA will increase significantly as potential users, operators and other beneficiaries come to understand the benefits of Wireline Equivalent FWA technology. As

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a result, appropriate spectrum will be allocated and rules for Universal Service created to enable regulators and operators to take advantage of these benefits.

WHAT IS THE LOCAL LOOP ?

The traditional definition is based around the copper pair which connects each telephone subscriber's line to the telephone company's central office (or "wire center"), although in recent years it has been modified to take account of changes in the feeder and distribution portions of the access network based on fiber and coax cable technology - the latter being associated with the emergence of telephony services from Cable TV operators.

Local Exchange Carriers (LECs) and CATV operators continuously struggle to understand the optimum combinations of hybrid fiber / copper / coax which can deliver the newer combinations of bandwidth and services demanded by tomorrow's end users. The puzzle has been further complicated by the rapid growth of mobile telephone users as a complement to the fixed networks, and the potential implications of the upcoming digital upgrades, PCS and satellite technologies on main line or second line growth and churn. Meanwhile, the recent strengthening of ISDN, data and Internet access demand has injected an additional set of factors into the planning and deployment challenges of access network planners as they try to become more flexible and responsive in the face of tougher competition and newer technology choices.

If we stand back and look at the local access network from the viewpoint of the urban customer, she probably sees a wired connection to a single LEC (over which she will shortly be able to receive bundled network service from a single network operator of her choice, which might or might not be the LEC). At the same time she might also have the option of an alternative connection from a CATV operator.

In addition, this customer might also have the choice of one or two cellular operators, one or two PCS operators, an MMDS operator, an LMDS operator, one or more satellite TV channels and a number of over-the-air broadcast TV channels (currently analog but one day - digital TV).

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WHAT'S THE (UNIVERSAL SERVICE) PROBLEM ?

By traditional definition, Universal Service means that a number of (residential) telephone subscribers in low density (mostly rural) areas must have their local loop and services subsidized in order to have it available within a reasonable time and at an affordable price, often benchmarked against the responsiveness and prices enjoyed by urban and suburban users where access costs are lower, operating utilization / efficiency is higher and competition is easier / fiercer.

This subsidy is often made up from several components, for example:-

- Geographic averaging of access line charges, regardless of distance or cost
- Cross-subsidy between long distance
- Cross-subsidy between business and residential connections and services
- End-user construction and mileage charges
- Explicit "infrastructure" subsidies funded by a levy on all users

The value of these implicit and explicit subsidies is estimated to be in the order of $20 billion per annum. However, these subsidies have little or no impact on the availability of advanced services to business or public service users / institutions in the areas concerned, on the provision of facilities competition, or the availability of even one Cellular / PCS, CATV, MMDS, LMDS or point-to-multipoint operator within the service area concerned. Each of these other services faces a non-viable investment / operational cost penalty similar to that faced by the monopoly LEC, but cannot benefit from the Universal Service subsidy. In addition, the customers concerned do not get the variety and choice of services or competitive benefits enjoyed by their urban or sub-urban counterparts.

Even the Universal Service subscribers do not often enjoy the benefits of the more advanced services, because the technology upgrades necessary to deliver these services cannot be justified on a standalone basis, don't work over longer loops, take longer to implement and / or don't qualify for the subsidy necessary to get them implemented. Lower density communities therefore remain disadvantaged (in spite of the significant subsidies applied) and cannot develop the communications based businesses and services necessary for economic development, education and information exchange in today's global economy. Unemployment remains higher than average and (rural) workers and youngsters must still move to the cities for meaningful employment where they find it increasingly difficult to compete with their more cyber-skilled urban counterparts.

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The Wireless Answer - A Case Study

Nortel is currently participating in a study in a developed country with telecommunications networks and policies similar to those in the United States. The study reviews the circumstances existing in more than five hundred communities with almost 300,000 present telephone service subscribers, and reflecting approximately 80% CATV availability and 20% cellular coverage.

Many of these communities include subscribers requesting additional connections for second line and Internet access, vacation homes requesting full fax/data/ISDN capability. Moreover, regulators are trying to ensure that the schools, clinics, libraries and public safety services in the communities are brought more into line with the services available in the larger towns and cities.

The preliminary study found that the CATV and cellular operators in the country cannot justify the build out necessary to serve these low density / low revenue communities. The study also found that the wireline telephone company would like to reduce its maintenance costs, travel times, subscriber complaints and waiting lists, but cannot economically justify the investments without major subsidy from the public sector, or its other customers in the main population centers.

To take one example from the study, there is a community with 550 existing subscribers, of which 150 are on 2- or 4-party line service, and the telephone company is holding some 50 orders for lines which it cannot fulfill including a small number of ISDN connections. These ISDN connections cannot be served by the existing cable pairs, either because special conditioning is required or the subscriber is more than two miles from the remote switch unit (which is served by an under-utilized 150 Mb/s fiber feeder). The estimated cost to convert the party lines to exclusive service exceeds $3000 per subscriber, and this investment would do nothing to help improve the held order, ISDN or limited CATV and Cellular coverage in the area.

Nortel believes that deployment of a Wireline Equivalent FWA system would provide significant relief. Under the FWA service proposed by Nortel, the telephone company would install or use a shared radio tower and site at the end of the fiber feeder, and immediately resolve the party line, unserved and ISDN situations at an installed cost of less than $1000 per subscriber excluding the incremental tower and site costs which would be a one-time subsidy.

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Over the next 10-20 years, the telephone company would use the FWA system to meet any further requests for service or upgrades, and to replace any faulty pairs, eventually allowing it company to abandon the exhausted copper plant. The installation and maintenance activities for the FWA system can be franchised out to a local technician within the community. This will save on travel costs and delays that would otherwise be incurred by the telephone company from the main city many miles away, and would improve the local response time to problems from within the community.

In addition to these direct and immediate benefits, the community would receive important additional advantages from the construction of the tower used for deployment of the FWA system.

The first added benefit is that any subsidy required is a single occurrence and related to the shared infrastructure rather than individual loops to specific subscribers which continue over time. Under this approach, any subsidy has been equitably used to offset the infrastructure cost for this community.

The second added benefit comes from the fact that a tower is now in place (and paid for), and as a result it is far more attractive for other operators to establish wireless coverage in the community. The same tower could support one or two PCS operators, a wireless cable or wireless Internet service provider, one or two LMDS service providers and paging/mobile data/vehicle tracking operators. The people living in the community now have more choices, and also can establish more local information and communications-based businesses and services within the community given the availability of a modern, reliable range of communications services.

A third added benefit is to the incumbent telephone company. In addition to its savings and improvements vis-à-vis the wireline operation, the company can offer additional services using the tower, fiber backhaul and switching facilities, or to wholesale those facilities to one or more third party operators so as to make available additional services. Thus, this wireless solution presents dramatic economies of scope for the incumbent telephone company and the community to enjoy as a result of the shared infrastructure.

The fourth added benefit is to the municipality and regulator, who will be relieved of any ongoing subsidy or consumer complaints that might otherwise result from a lack of choice or inability to develop businesses or services within the community. Technicians presumably

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would be easier to attract to the community to handle all the services available on a franchise basis, in addition to satellite TV dishes, in-building wiring and/or modifications, electrical installations and other related work.

A fifth added benefit is to the carrier leasing the space. Not only is there reduced capital outlay, but the time to get into service is reduced because site acquisition issues including planning and zoning have already been resolved.

Moreover, to the extent that the Federal Communications Commission adopts the proposed NII / SUPERNet service that will allow schools to develop wireless local area networks connecting the classrooms, the FWA (along with LMDS) service can provide a fast and robust connection from the schools to the telecommunications infrastructure of multiple service providers.

WHY WIRELESS TECHNOLOGY CAN HELP

Wireless Enables Change and New Forms of Competition

Notice that all of the newer services noted above (Cellular, PCS, MMDS, LMDS, Satellite and point-to-multipoint) are different applications of wireless technology. There have been relatively few new services deployed over cabled technologies (copper, fiber, coax). Even ISDN, ADSL, Cable Modems, Switched Digital Video, Video on Demand or residential T1 delivery have not yet been widely or rapidly deployed in all urban areas, let alone suburban and rural customers. Their deployment will be gradual and non-universal because of the inability to do selective infrastructure upgrades on a customer-by-customer basis for niche services.

By its very nature, wireless technology is much quicker and easier to deploy for the introduction of new services and competition. Indeed, wireless has a long and proud history of enabling industry changes and new competition, for example:-

- **Long-haul digital microwave**
  (which enabled competitive long distance carriers to develop rapidly in the 1980s)
- **Cellular telephony**
  (which enabled the mobile telephone industry to achieve almost 50 million North American users in just over ten years)
- **Short-haul digital microwave**
  (which enabled many alternative access providers to reach more medium and large business premises quickly and cheaply throughout the 1990s)

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Wireless Enables New "Fixed / Portable / Mobile" Hybrid Solutions

The newer digital cellular and cordless wireless technologies now being deployed worldwide at 400 / 800 / 900 MHz or 1800/1900 MHz can be configured to also provide fixed installations with options for mobility and local portability plus the newer methods of retail distribution and usage-based tariffs pioneered by the cellular industry during the 1980's.

Deployment depends on the ability and viability of the various spectrum licensees to install sufficient base stations and backhaul capacity in enough geographic areas, plus acceptance by residential, personal and business users of the different pricing, service and performance / quality aspects of these systems.

Wireless Provides Broadband Services and Access

The newer MMDS, LMDS, point-to-multipoint and satellite technologies / services provide a range of access services from fractional T1 (n x 64 kb/s) through to LAN/WAN, multi-channel broadcast or interactive video and broadband data up to DS-3 (45 Mb/s) rates, at various frequencies from 2500 - 38,000 MHz (2.5 - 38 GHz), competing with the more traditional CATV (coax), Telco (Fiber) and data (twisted pair) technologies and operators. Deployment coverage, commercial viability and user acceptability will be determined progressively over the next few years, but there is no doubt that wherever and however it occurs, it will be far cheaper, quicker and less disruptive than an equivalent cable-based deployment.

Fixed Wireless Access can Provide "Wireline Equivalent" Access

Until recently, wireless access technologies could not match the combination of cost, performance, quality and reliability characterized by the copper (or fiber/copper and coax/copper) local loops which form the basis of today's 200 million telephony access connections in Canada and the US. While this is still true for the vast mass of connections in the higher density city and downtown areas, it is no longer true for medium and lower density applications in the smaller cities, towns, sub-urban and rural or remote areas.

A "new generation" of Fixed Wireless Access systems can operate in various frequency ranges between 1500 - 4500 MHz (1.5 - 4.5 GHz) and provide "Wireline Equivalent" service to hundreds or thousands of subscribers within a one to twenty mile service radius.

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Subject to spectrum and license availability, these newer FWA systems could be deployed by incumbent LECs to solve some of their service response and cost problems, especially in sub-urban, rural, high cost and remote areas. They can also be deployed by new operators or facilities providers to overlay competitive services on a wider geographic area with relatively low penetration levels (e.g. 1-20%) or even by CATV and LEC operators to provide specific ISDN, data or second line services throughout their franchise area in advance of cable upgrades or capacity reinforcements, and as a faster response against new entrants.

WIRELINE EQUIVALENCE

This term covers a number of parameters which form an implicit or explicit part of the traditional copper loop service connected to the established fixed network switches, multiplexers and leased line cross-connect centers for both public and private network applications.

These factors are important for several reasons:-

- End users have significant cumulative investments in fixed network telephones, answering machines, fax machines, modems, PC hardware / software, PBXs, key systems, muxes, routers, and other terminal equipment which they expect to work regardless of the local loop technology employed by their service provider.

- End users have a different set of experiences and expectations for their basic LEC (universal) telephone service and its connections, prices, performance and reliability than they attribute to or expect from alternative operators and services (such as CATV, Cellular and PCS).

- Wireline and fixed network operators require very high degrees of compatibility and transparency of performance, operation, billing and network management for any new local loop technology (including wireless). Deficiencies or uncertainties in this area can result in huge volumes of customer complaints, expensive modifications to OA&M, billing and front-office systems, financial or other penalties from regulators and long (expensive) delays before remedial fiber or copper rehabilitation / reinforcement can take place, with potential revenue, competition and cost impacts.

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Table 1 below summarizes the main factors involved, and how they compare between wireline, mobile and Wireline Equivalent FWA technologies. In general, the broadband wireless systems are designed to also emulate the wireline factors where applicable.

The application of any technology requires a clear agreement on the various inputs, assumptions and outputs required, before a single dollar is spent on construction or implementation. For wireless access systems the following factors must be addressed:

Inputs	**Environment**	terrain, climate, powering
	Services	voice, fax, data, bandwidth, mobility, portability
	Existing Plant	infrastructure, interfaces, OAM&P, overlay vs greenfield
	Coverage	clusters, dispersed, uniform, sporadic
	Penetration	Initial, growth, predictability, unit costs
	Quality	Reliability, blocking, delay, repair & restoration times
	Regulatory	Spectrum, tariffs, depreciation, standards

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TABLE 1 - WIRELINE EQUIVALENCE TECHNICAL COMPARISONS

Parameter	Wireline Technologies	Fixed Wireless Technologies	Mobile Wireless Technologies
Voice Coding	64 kb/s PCM or analog	32 kb/s ADPCM or 64kb/s PCM	4-16 kb/s compressed coding
Voice Quality	MOS = 4.3*	MOS = 4.0 - 4.3*	MOS = 3.5 - 4.1*
Group 3 Fax Rates	All to 14.4, or 28.8/ 33.6k when available	Same as wireline	2.4, 4.8, 9.6 or 14.4k (19.2k future)
Modem Data Rates	All to 33.6k	Same as wireline	2.4, 4.8, 9.6 or 14.4k (19.2k future)
Digital Data Rates	All to 56/64, 128, 384k	Same as wireline	9.6,14.4k or 19.2k or Packet Mode
T1/E1 Delivery	Fractional or Full	Same as wireline	Not Practicable
Customer Interfaces	° RJ-11 or equivalent ° ISDN BRI ° Leased Line Standards ° Data Standards	Same as wireline	RJ-11 and data interface emulations via adapter boxes on AMPS, PCS or GSM air interfaces
Engineered Traffic Capacity per line	1 - 36 ccs	Same as wireline	1 - 10 ccs typical
Economic Access Grade of Service	Better than 1% or 0.1% blocking	Same as wireline	Typically 2-20% blocking
Long term Bit Error Rates	1 in 10^{-6} to 1 in 10^{-8}	Same as wireline	1 in 10^{-3} to 1 in 10^{-5}
One-way Loop Delay	<5 milliseconds	<20 milliseconds	50 - 150 milliseconds
* MOS scale = 1 - 4.5 basis		(MOS = Mean Opinion Score)	

FIXED WIRELESS ACCESS TECHNOLOGIES & STANDARDS

Table 2 below summarizes the three main classes of wireless access technologies. The first two are characterized by their need for rigidly standardized air interfaces in order to support mobility / portability and compatibility with retail terminals. The "Application Specific" class is characterized by the need to support standardized (fixed) interfaces at each end of the system, with non-standardized air interfaces optimized for the different services, capacity and applications supported.

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TABLE 2 - WIRELESS ACCESS TECHNOLOGIES

		Fixed Cellular and PCS	Cordless	Application Specific
Original Application		Outdoor Mobile & Wide Area Portable Telephony	Indoor, campus, PBX and local portability	MMDS LMDS FWA Point-to-Point Point-to-Multipoint Satellite
Wireless Access Application		Low-tier POTS (esp Developing Countries)	Wireline Extension & portability	Full & Advanced POTS, business, TV and broadband. Universal Service
Services	Voice	Compressed	Compressed or 32k	32k or 64k
	Fax	Limited Speeds	Limited Speeds	Full Speed
	Modem data	Limited Speeds	Limited Speeds	Full Speed
	Digital data	Limited Speeds	Limited Speeds	56kb/s - 45Mb/s
	ISDN	No	No	BRI and PRI
	Internet Access & LAN Bridge	Limited Speeds	Limited Speeds	28.8kb/s - 10Mb/s
Standards		AMPS (FDMA) IS-54 & IS-136(TDMA) IS-95 (CDMA) NMT (FDMA) GSM (CDMA)	CT0/1 (Analog) CT2 (TDMA) PACS (TDMA) PHS (TDMA) DECT (TDMA)	Vendor Specific
Frequency		400 / 800 / 900 MHz 1800 / 1900 MHz Licensed / auctioned	45 MHz 860 MHz 1800 MHz Often unlicensed	Various frequencies Mostly licensed Some auction or fee-based charging
Typical Range	City	1 - 2 miles	500 - 1000 feet	1 - 2 miles
	Urban	2 - 5 miles	1000 - 2000 feet	2 - 5 miles
	Suburban	5 - 10 miles	1 - 2 miles	5 - 10 miles
	Rural	10 - 30 miles	2 - 3 miles	10 - 30 miles
Network Elements	Type	Centralized Overlay with own Controller	Cluster / Zone Controllers	Distributed
	Switch & Interface	Mobile / Trunks	POTS or BRI	Various
	Terminals	Fixed/Mobile/Portable	Fixed / Portable	Fixed / Portable
	Base Station	Large Cell Site	Pole/Building Mounted	Varies
	Base Station Controller	Yes	Yes	Generally None

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CONCLUSION - WIRELESS AND UNIVERSAL SERVICE

Unresolved Questions

The concept and rules for Universal Service were created in the 1930's when urban consumers could only obtain telephone service from a single network operator, twisted pair cable was the only economical or reliable technology for connecting subscribers to the operator's switch and voice telephony was the only telecommunications / information service available. The emergence of television (funded by broadcasters, advertisers and consumers), fax and data terminals, leased line and private network infrastructures, cellular / mobile telephony / data and multiple telecommunications operators over the past sixty years has complicated the decisions of which services, operators and technologies should be subsidized and how much regulation should be applied to the standards of service and quality available via the different technology and operator combinations. The US Congress recognized that there is a need to make advanced services available to all Americans and indicated so in the section of the Telecommunications Act of 1996 which dealt with Universal Service reform.

Should Cellular / PCS be recognized as a "Low Tier" basic universal service (with or without mobility) ? Does this mean that wireline POTS is now regarded as a "premium" offering, and which level of service should be subsidized in order to reach customers in high cost / low density areas ? Is mobility an essential "lifeline" service, or does the widespread availability of mobile telephones lessen the obligations on wireline POTS to maintain service during emergencies or power failures ? Should subsidized Universal Service subscribers expect to operate the same fax, data and other advanced POTS services as their urban counterparts ? Why shouldn't business telecommunications users be Universal Service subsidized so that they can flourish in rural or high cost areas ? What benefit will subsidizing health, education and public service as Universal Service users have on the other residential, business and personal users within the community?

Since more people now have televisions than telephones, and urban customers (will) enjoy a greater choice of integrated voice / data / video and "Information Highway" access from the multiple technologies and operators available in urban areas, should Universal Service subsidies become more concerned with giving suburban and rural customers the same degree of choice, flexibility and competitive access as their urban colleagues? Is it appropriate that tenants in apartment or multi-tenant buildings can have their access to telephone and video / information networks determined or restricted by their landlord and his arrangements with selected network operators or service providers?

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Is it appropriate that residents and businesses in local sub-divisions can have their access to telephone and video / information services determined or restricted by their developer or municipality and their arrangements with selected network operators or service providers?

All the while that Universal Service concepts and subsidies are limited (implicitly or explicitly) to cabled technologies and the resultant local monopolistic provision of cabled access, most of these questions and anomalies will remain, and we will continue to witness an annual frenzy of raising and distributing $20 billion or more on non-flexible and poorly targeted partial solutions.

Market and Spectrum Impact

The availability of spectrum and systems for Cellular and PCS network deployment, MMDS, LMDS and SUPERNet is in place or underway, although it is not yet clear that any commercial priority or regulatory incentive is in place to ensure that these new services and choices will become available to rural or low density populations in any particular timeframe. Meanwhile Universal Service, Interconnection and Access Charge reforms remain centered around fiber and copper based solutions operated by incumbent LECs while CATV and Competitive Access Providers must continue to concentrate on targeting the higher revenue and higher density business, SOHO and long distance users. Every one of these customers represents an economic loss to the incumbent LEC, increasing the cost burden on the remaining lower revenue / lower density subscriber base, triggering even higher Universal Service subsidies in the future. The introduction of Wireline Equivalent FWA technologies and systems would enable LECs, CATV operators and CAPs to more quickly and cheaply expand their basic service coverage to medium and low density areas, and minimize the costs and subsidies needed to improve consumer choice and keep prices affordable, more in line with urban situations. Wireline Equivalent FWA systems need different types / amounts of spectrum than Cellular, PCS, MMDS and LMDS. They can operate at higher frequencies than mobile technologies, but need better coverage (i.e. lower frequencies and lower power levels) than broadcast or broadband systems.

Wireline Equivalent FWA systems exist and are being deployed worldwide by vendors such as Nortel (Proximity I), Lucent Technologies and DSC Communications and are currently being evaluated by key North American operators, many of whom are already using them in their overseas projects and operations. The US and Canadian markets however remain undeveloped because there is currently no suitable spectrum allocated for these technologies and applications.

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Recommended Actions

The actions needed to unlock the spectrum and the market and to enable the Universal service and other benefits to be realized are:

A. Ensure that the current reviews and re-definitions of Universal Service, Interconnection, Access Competition and Access Charge Reform take proper account of the role that wireless (in its various forms) can play, and not ~~to~~ be biased towards cable solutions.

Nortel has submitted appropriate comments to the FCC in dockets on these topics: En Banc on Spectrum Policy, Docket 96-6 Flexible Service Offerings in CMRS, Docket 96-45 Universal Service, Docket RM 8837 DSC Petition for FWA Spectrum. The FCC also needs to hear more expression of interest about Wireline Equivalent FWA from organization such as CITI, NTIA, TIAP, NARUC and the various operator groups and representatives, as well as consumer and community interests.

B. Ensure that suitable spectrum is allocated and that appropriate licensing and payment terms are applied which do not prejudice Universal Service or regulated service performance and price benchmarks.

Again, Nortel has submitted appropriate comments to the FCC and Canadian authorities during the past year and is working aggressively and in cooperation with other interested operators, regulators and vendors in the relevant ITU, ETSI, CITEL, South and North American regulatory forums to determine possible frequencies, bands and rules. Again, expressions of clear interest from non-vendors is also needed to secure the necessary attention and priority of the regulators.

To the extent that any US and Canadian allocations for FWA are harmonized with the allocations in the rest of the Americas and in Europe, there will be greater global export opportunities for North American manufacturers. In sum, an FWA spectrum allocation will bring numerous direct and indirect benefits to individuals and businesses throughout the United States and Canada.

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FURTHER INFORMATION

The following gives a short response to a number of frequently asked questions about Wireless Access and its role in delivering Universal Service. Copies of the presentation charts which accompany this paper are available on request or from the Nortel web site at http://www.nortel.com.

Frequently Asked Questions about Wireless in Delivering Universal Service

1. **Can wireless technology be used in place of wireline from a regulatory perspective. If not, should it be allowed.**

   Wireline Equivalent FWA systems can (and should) be used in place of wireline from a regulatory perspective, but require the allocation and licensing of appropriate spectrum which has not yet occurred in the US or Canada. The use of Cellular and PCS wireless technology (including PACS) is already allowed, except that incumbent wireline operators are generally restricted in their acquisition or use of Cellular, PCS, MMDS and LMDS spectrum. So far as Universal Service is concerned, a basic issue (covered in this paper) is the definition of "basic service" for regulatory and subsidy purposes, and whether it will differentiate against "low tier POTS" versus "full POTS", which advanced services and non-residential customers will be subsidized and whether the rules will be changed to more fully recognize the role that wireless can play.

2. **How will fixed wireless service and mobile wireless services be differentiated? Should there be subsidizing from one area to the other if they both are utilizing the same infrastructure?**

   There are actually four services implied here :

   - The mobile service offered by cellular and PCS operators, directly or via resale
   - Any fixed (or hybrid fixed / mobile / portable) options based on these mobile technologies and networks. These services do not support the same feature, functionality or quality criteria as fixed wireline networks, and are not subject to the same regulatory and service rules.
   - Fixed wireless installations based on cellular / PCS technologies but connected to fixed network switches and services. These are almost Wireline Equivalent but often cannot transparently support all the features, functions or quality aspects of wireline access.
   - Wireline Equivalent FWA. This appears to the user and the service provider as a transparent equivalent to wireline service, and does not need to be differentiated.

   As described in the paper, there are specific benefits to sharing and subsidizing the wireless infrastructure (e.g. towers and backhaul facilities) in low density areas, rather than subsidizing the individual connections and services to customers. This would simultaneously benefit ALL users in the community (not just residential voice subscribers). Each user would subscribe to the service (s) and operator(s) of their choice, as they do in urban and high density areas.

3. **If wireless technologies are used to provide multiple services (voice, telephony, cable, 2-way video) over a single infrastructure, how should costs be allocated from a universal service perspective?**

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Each municipality could take responsibility for determining and funding its infrastructure service needs (as it does for power, drains, water, airports etc.), and then leave the relevant operators to deliver and maintain the services off of that infrastructure. Some municipalities already provision the ducts for new streets and sub-divisions and let out the franchise for running telephone and TV cables through them. In the "Wireless Proposition" described in this paper, municipalities could similarly establish a community wireless tower and franchise out the rights to operate and maintain multiple wireless-based services and the backhaul feeders. In some case, the "towers" could actually be existing buildings, municipal structures or utility poles and towers. The Universal Service fund could be used to assist municipalities with these infrastructure costs, reducing the charges to local taxpayers or the service franchisees.

4. **Should competitive entrants be allowed to provide wireless local loop? If a new wireless local loop provider is not an incumbent provider, how should universal funds be distributed? Should competitive providers be allowed to subsidize local rates with enhanced services? What are the prospects for wireless local loop overlays for second lines.**

As described in the paper, low density and rural residents and businesses should enjoy the same competitive range and choice of services as their urban counterparts. This has traditionally not been achievable with a cable paradigm, but can be achieved using a range of wireless based access systems. Universal Service funds should be used to equalize the shared infrastructure costs for all the operators serving the community, and the incumbent LEC should also be able to use Wireline Equivalent FWA to reduce his costs and exposures on cable plant to remote and higher cost customers.

5. **How are common carriage issues handled over wireless networks? Is access based on existing channels or to pure bandwidth (i.e. what levels of the OSI hierarchy are accessible)?**

Traditional fixed networks have always provided full time and bandwidth for each subscriber line to the switch or network interface, at which point users compete for network capacity and resources "on demand" or as part of a leased line service. Modern switching and digital loop carrier access systems place the "concentration" point as near to the users as possible, so as to minimize the backhaul facility costs. Wireless networks can similarly be engineered to provide full-time channels and bandwidth to each user, or to allocate the channels / bandwidth "on demand". The issue (if there is one) is in the traffic and blocking assumptions used to engineer the access networks and services. Wireline networks are typically engineered for a 0.1% probability of failure whereas mobile networks are typically engineered for 2-20% probability of failure. Wireline Equivalent FWA systems can be similarly engineered for 0.1% blocking, so long as the cost of spectrum and base station capacity / equipment is properly allowed for. The regulatory question is therefore whether to insist on any specific blocking levels when engineering for Universal Service.

6. **How are privacy and public services (911 and 411) maintained over wireless local loops? How will provisions for law enforcement (wiretapping) be administered?**

These issues are creating a lot of difficulties and costs for mobile operators, and some of this will spill over into fixed installations based on these technologies and networks.

Wireline Equivalent FWA systems connected to fixed network switches and services do not have these problems, since the provisioning, management, alarm and wiretapping capabilities still exist within the fixed network standards. The access traffic can be monitored in the conventional way at the subscriber premises, or on the T1 links at the base station or switch interface (or in between) using standard fixed network access equipment. The air interface for Wireline Equivalent FWA can be monitored and decoded by authorized security agencies using their normal de-encryption techniques.

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7. **What will be the costs of dismantling existing local providers, such as termination packages, pensions, amortizing existing investment equity? How will these costs be financed?**

The impact on incumbent operators of new competitive entrants should be no worse for low density / high cost areas than in higher density / lower cost areas, and any re-sizing costs would appear to be a natural consequence of the "more competition / consumer choice" legislation enacted by congress and implemented by the FCC and State regulators. If wireless technology allows competitors to enter lower density market segments more quickly or more cheaply than hitherto then this is just another equalization of the differences between urban and rural areas. However, the availability of suitable spectrum and Wireline Equivalent FWA systems for use by incumbent LECs (as well as competitors), and the infrastructure sharing models suggested in this paper, would create opportunities for the LECs to respond to the competition, benefit from the wholesaling of towers and backhaul infrastructure, and if necessary retire their cable plant over an appropriate (long) period of time by using Wireline Equivalent FWA to progressively add new subscribers and replace faulty plant. Without Wireline Equivalent FWA, incumbent LECs would have no defense against new entrants (whether cable or wireless based) and would have to watch their investments and revenues erode without the financial justification for renewal, refurbishment or enhancement. Their calls on the Universal Service subsidy fund (as currently envisaged) would probably become more frequent and more significant.

8. **What will the new regulatory role be in this environment?**

This is currently a contentious issue in relation to the cellular, PCS, MMDS and LMDS operators that do not fall under the same (State) regulation as Local Exchange Carriers and Universal Service mechanisms. The availability of Wireline Equivalent FWA systems to LECs (and others) would not of itself alter these distinctions. Regulatory aspects regarding Universal Service subsidies would be simplified and enhanced by the tower / backhaul sharing models suggested in this paper.

9. **What are the value-adding and cost-reduction benefits of the wireless local loop? What are the drawbacks?**

a. **for basic fixed-location services?**

Wireless access based on mobile technologies and networks will probably add confusion because of the feature, functional and quality differences compared to traditional wireline loops. Until consumers get used to the existence of "low-tier" and "standard" POTS, Regulators can expect an increase in complaints based on differences perceived in the non-regulated services. Consumers traditionally tolerate these differences (often at a premium price) in return for the value of mobility and portability but this would not apply to fixed installations (as opposed to fixed / mobile hybrids configurations).

Wireline Equivalent FWA connected to fixed networks of the incumbent LEC, CATV operator or new entrants should be transparent to the user, and the value add / cost reduction benefits will accrue to the operator. The resultant benefit to consumers would be in having more and healthier facilities based local access competition and lower Universal Service taxes or levy's.

b. **for mobile and advanced services?**

Mobile operators could use a mixture of cellular / PCS technologies and the Wireline Equivalent FWA technologies to address broader market segments, reaching into the higher usage and higher bandwidth customer base (residential and business). Using mobile spectrum (and the associated overheads) for fixed services is wasteful and inefficient, and limits the revenues obtainable form the premium mobility services for a given allocation of mobile CMRS spectrum.

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Advanced services (other than mobility) are generally operated or introduced on the fixed networks, and would not be available to fixed installations based on mobile technologies and networks. Wireline Equivalent FWA systems are normally transparent to the introduction of advanced services, and some of the really advanced services (such as MMDS, LMDS and SUPERNet) are only available via Wireline Equivalent FWA.

c. **What value should be given to the rapid deployment ability for wireless networks?**

This value will be assigned by the new entrants and incumbent LECs themselves (and will different for each) and reflected in their business cases. The danger lies in viewing the PCS spectrum auctions as reflecting the potential value of spectrum for FWA. The value of a fixed access connection is bounded by the (subsidized) cost of a wireline loop which is itself artificially distorted by the traditional cross-subsidy applied to access charges. New entrants can choose not to bother to invest, and just rely on resale of the incumbent loop. Incumbent LECs can choose to let their monopoly continue and keep the subsidy mechanism intact (or growing).

The real value or benefit of rapid deployment capability therefore accrues to the regulators and consumers who enjoy the benefits of accelerated local access competition and increased choice of services and providers, especially in medium and lower density areas.

d. **What are the quality of service factors of wireless service? How do they differ from wireline.**

These are summarized in Table 1 of the paper.

10. **How does the definition of universal service affect the viability of wireless local loop? In what ways are wireless networks more vulnerable? More resilient?**

The main factor affecting wireless access is any definition of what the Universal Service is defined to be. If it is based on low-tier POTS then the Cellular and PCS technologies can address it at the expense of the regulated wireline providers. If Universal Service is defined to be the traditional basic POTS service then only Wireline Equivalent FWA technologies can be used, and these will require the allocation of suitable spectrum to the appropriate operators.

Wireless networks are more vulnerable to physical obstruction (e.g. tall buildings or new buildings), and at frequencies above about 4 GHz they become increasingly vulnerable to weather and foliage variations or multi-path fading, especially in wide area or non line-of-site situations. Fixed wireless customer installations are also more vulnerable to local ac power failures or disconnection's which exceed the provisioned battery life.

Wireless access is less susceptible (i.e. more resilient) to physical or storm damage, civil works, lightning damage, flooding, gas or animal / bird damage than underground or aerial cable plant. Failures and maintenance activity are concentrated at the base station and customer locations (nothing in between) where proper engineering and security precautions are easier to enforce.

11. **How do economic wireless and wireline models differ as one moves from the PSTN to higher bandwidth service?**

As a general point, an installed cable network (fiber, coax and /or copper) can only be upgraded within its own technical boundaries, which were largely set when the cable was purchased / installed or when the last major electronics investment was made. To introduce a new or different service requiring a new (type of) cable or a major electronics upgrade becomes financially and operationally prohibitive.

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Wireless technology on the other hand allows different wireless systems and bearer technologies (i.e. air interfaces and modulation schemes) to coexist on the same backhaul and tower infrastructures at the same time, and new ones to be added at any time. Thus PCS, MMDS, LMDS and Wireline Equivalent FWA can all coexist or be added independently without financial or operational penalty - and indeed can be operated by different or competitive service providers (not easy with cable !)

a. **What are the costs of upgrading wireless networks versus wireline networks?**

In general, wireline networks takes years and lots of new investment to upgrade or enhance (as opposed to just filling out installed capacity), and are virtually impossible to redeploy or rearrange (and certainly not quickly or easily).

Wireless networks can be upgraded via software downloads over the air, enhanced, replaced or added on an incremental basis with little or no disruption to existing or other services sharing the same infrastructure. Wireless equipment at the base stations and customer premises can be removed and re-deployed simply and quickly to match changing patterns of growth and demand. New base station sites can be operational within weeks once the necessary wayleave, access and legal agreements are in place. Many of the Wireline Equivalent FWA applications in suburban areas should be able to share PCS towers already in place.

b. **Is wireless ISDN an appropriate wireless service, and if not what are the alternatives?**

Wireline Equivalent FWA systems are designed to provide ISDN BRI capability, mostly in the 1997/98 timeframe. LMDS provides ISDN capacity and interfaces would depend on each vendor's roll-out priority (some versions are offering 10Mb/s ethernet access to the home plus one or two voice lines). ISDN is not an appropriate service for wireless access based on mobile technology and air interface standards, although GSM claims to have some capability in the future through concatenation of timeslots and ISDN-compatible air interface protocols. The IS-95 Generic C proposals use ISDN interfaces to their switches but it is not clear whether / when they would offer ISDN interfaces and services to their terminal users. Many point-to-point and point-to-multipoint wireless systems offer ISDN and data interfaces, but these are mostly aimed at business and leased line applications rather than residential.

The ISDN alternatives to wireless access are cable based, but with limited range and notorious deployment costs / difficulties to overcome installed copper plant deficiencies. Alternatives for internet access are cable modems on CATV coax, MMDS and CATV broadcast with low speed back channels and latest generation fiber access systems with residential ethernet connections.

12. **What are the differences in wireless and wireline network costs for operator equipment and customer CPE?**

Answers are radically different for mobile-based technologies and networks compared with Wireline Equivalent FWA technologies.

Mobile-based systems tend to carry more overhead and equipment costs in the base stations, controllers and switching networks (HLRs, VLRs etc., even for fixed), although the operators tend to regard these as "being there" and only treat the fixed installations as incremental (capacity) costs. Terminals on mobile-based systems are claimed to be "cheaper" but this is based partially on the perceived price of (subsidized) mobile terminals and ignores the extra cost of units required to drive standard telephones and CPE, or needing additional installation and battery backup capability to meet "standard" performance and lifeline requirements. Network costs increase significantly in high traffic / high usage applications.

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Wireline equivalent systems normally connect directly to standard ports on fixed network switches and do not require additional controllers or complexity at the base stations. Wireless CPE tends to be more expensive and requires proper installation by trained resources, but then continues to operate to the same specifications as wireline CPE. Alarms and diagnostics from the CPE are generally fed back to the operator's management systems to ensure full control, integrity and performance analysis for each subscriber and line.

a. **How should decisions be made for tradeoffs of costs between CPE and operator equipment?**

Decisions should be based on the overall cost per subscriber or line installed (allowing for multi-line applications and CPE sharing) plus the installation and ongoing maintenance life cycle costs. franchising, leasing and charging for CPE (in lieu of construction or mileage charges under current wireline practices) is a possible option to reduce operator investment.

b. **As customer premise equipment becomes more complicated, how will service questions and maintenance be dealt with?**

The same as they are for wireline connections and services. This will create a number of problems for mobile network operators who do not generally deal with CPE and front office processes for provisioning and maintenance, but will be the same as normal for wireline operators using Wireline Equivalent FWA

13. **As the overall network intelligence increases, will wireless networks be able to incorporate advanced features such as SONET-like rerouting, Signaling System 7 (SS#7), ANI/Caller ID, call blocking, and advanced database look-up services? How will interconnection and networking exist in an internet worked wireless/wireline environment?**

This is an open question for mobile networks and their operators, and the convergence of mobility, AIN and fixed / mobile network switching in the next few years will try to simplify the problems. Wireline Equivalent FWA is transparent to these issues which are all based in the switching or backhaul / feeder networks.

14. **What are the different network architecture models for providing fixed wireless service? Can these networks also support mobile wireless services?**

These are summarized in Table 2 and elsewhere in this paper, and in the associated presentation charts.

15. **How do equipment costs differ between wireline and wireless services? In particular, how does the costs of the CPE affect the total costs of the network? What is the net savings/ costs to the operator? To the consumer?**

Wireline is cheaper for higher density city and urban deployments, or where subscriber penetration and traffic density is very high (e.g. medium and large business users). Fixed wireless access based on mobile technologies is competitive with copper for "low tier" POTS in urban and suburban densities, but is very restricted on traffic density and usage. Wireline Equivalent FWA is cheaper than wireline for loops greater than 1-2 miles in urban, suburban and rural deployments, or where subscriber penetration in an area is less than about 60 or 80%. Wireless is the only economic method in some high cost or remote and rural situations.

CPE accounts for between 30 and 70% of the installed cost, depending on technology and configuration.

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16. **Will CPE equipment support both fixed and mobile wireless services? How does the economics for producing fixed wireless CPE compare to producing wireline CPE? To mobile CPE?**

CPE equipment based on mobile technologies connected to mobile networks can offer combinations of fixed and mobile service, but the network must be engineered with the appropriate mobility overheads in mind. The costs of fixed CPE for both mobile-based and Wireline Equivalent based FWA are similar for similar functionality and performance (e.g. extension driving capability and battery backup etc.) even though the services offered might not be the same.

Wireline CPE is the cheapest available, starting with DTMF telephones from $20 and faxes, modems and answering machines at $99.99

17. **What are the benefits of fixed wireless networks over wireline networks? What are fixed wireless service's drawbacks?**

The principal benefits of fixed wireless access are speed of deployment, flexibility for overlaying new and different services, and cost of provision and maintenance over the life of a particular customer installation, especially for new entrants at lower penetration rates. Drawbacks are the need to obtain suitable / adequate spectrum for the service or deployment concerned (and associated auction / license fees), the contention for tower sites plus the logistics and costs of tower site acquisition, construction and sharing.

18. **How will billing to supported by wireless local loop equipment? Will the network be able to determine if source signals are from fixed wireless CPE, mobile CPE, and hybrid CPE, if different pricing schemes are determined?**

Wireline Equivalent FWA is transparent to the fixed network billing processes.

19. **How will numbering be supported in wireless local loops? Will there be number portability among fixed wireless mobile, and wireline subscribers? How will wireless local loops provide solutions for "personal numbers", e.g. one number for home, office, mobile?**

This is a complex issue for wireless access based on mobile technologies and networks, which have different numbering methods than wireline operators, but is no worse than the problems faced for the mobile users. Wireline Equivalent FWA is transparent to the fixed network numbering and LNP processes.

20. **Will enhanced services like faxes and on-line services be affected by wireless local loops? If services are digital, what are the implications for legacy and end-user fax and modem equipment? What are the implications for new generation equipment?**

Wireless access based on mobile technologies (whether connected to fixed or mobile networks) can only support fax and data speeds up to 9.6k, 14.4k or possibly 19.2k. They are also spectrum and capacity limited in terms of traffic density and usage, and the cost of adding more cell sites or sectors to increase frequency re-use could be significant. Blocking levels and probability of call rejection or drop-out is typically higher with mobile systems, partly due to interference from (or the unpredictability of) mobile users.

Wireline Equivalent FWA is designed to handle fax and data traffic at full PSTN rates (currently 28.8k or 33.6k), and can also offer direct digital interfaces at 56, 64, 128, ISDN BRI or 384k rates). They are still limited by spectrum usage and capacity but are designed for higher bandwidth and

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usage services with engineered blocking levels and grades of service based on fixed network predictability.

21. **What will be the bandwidth capacity for wireless services? Will networks support bursting capabilities if there is capacity on the network? Will data be supported over the same channel? If not, how will they be supported if at all? Will digital wireless services be compatible with ISDN.**

Wireless access systems based on mobile technologies are limited by the standardized bandwidths, air interfaces and switching capabilities of the mobile networks. Systems designed for Wireline Equivalent FWA, MMDS and LMDS applications have the bandwidth and spectrum capacity needed to suit the application, and can be evolved by each vendor to meet new or different demands and incorporate new technologies and algorithms. Data is definitely supported over the same channels as voice, and some systems switch the bandwidth dynamically to suit the voice, fax or data service and rate in use. ISDN is definitely compatible with Wireline Equivalent FWA, including the availability of D-channel and B-channel packet services.

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LIST OF ACRONYMS

ADPCM	Adaptive Pulse Code Modulation
ADSL	Asynchronous Digital Subscriber Line
AMPS	Advanced Mobile Phone System/Service
ANI	Automatic Number Identification
CATV	Community Antenna Television
CITEL	Inter-American Telecommunications Commission
CITI	Columbia Institute for Tele-Information
CPE	Customer Premise Equipment
DTMF	Dual Tone Multi-Frequency
FDMA	Frequency Division Multiple Access
FWA	Fixed Wireless Access
GSM	General Service Mobile
ISDN	Integrated Services Digital Network
ISDN BRI	ISDN Basic Rate Interface
ISDN PRI	ISDN Primary Rate Interface
LAN	Local Area Network
LEC	Local Exchange Carrier
LMDS	Local Multipoint Distribution Service
LNP	Local Number Portability
MMDS	Multichannel Multipoint Distribution Service
MOS	Mean Opinion Score
OA&M	Operations, Administration and Maintenance
OAM&P	Operations, Administration, Maintenance and Planning
PACS	Personal Access Communications System
PBX	Private Branch Exchange
PCM	Pulse Code Modulation
PCS	Personal Communications Service
PHS	Personal Handi-phone System
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
SOHO	Small Office Home Office
SONET	Synchronous Optical Network
SS#7	Signalling System Number 7

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