Key benefits of Bluwan FTTA: A TDD PTMP architecture

A white paper

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1 Executive summary

Whether you are a B2B[1] operator delivering services to enterprise customers, a MNO[2] with backhaul requirements or a B2C[3] operator delivering voice, broadband and TV, in today's environment you face a common set of network challenges. Operators are looking for a network that will enable their business objectives of delivering flexible services, rapid customer acquisition and the maximum revenue per unit of capacity at the lowest cost per unit.

In this paper, we examine how wireless solutions, in particular those that can harness wide blocks of TDD[4] spectrum in a PTMP[5] architecture, can provide the answer in terms of a high capacity flexible network with low CAPEX and OPEX requirements, especially when compared to alternatives such as xDSL, PTP[6] microwave, fibre and leased line. We look closely at higher spectrum bands such as 12 GHz and 42 GHz, where cost-effective spectrum is available which can be used in an efficient TDD mode.

The paper compares the CAPEX and OPEX drivers for wireless PTMP and PTP solutions with the conclusion that PTMP has significant cost advantages.

Finally we look closely at the network requirements for the three operator cases (B2B, MNO backhaul and B2C) and how a TDD PTMP wireless solution such as Bluwan's Fibre Through The Air (FTTA) can be a compelling solution.

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[1] Business to Business

[2] Mobile Network Operator

[3] Business to Consumer

[4] Time Division Duplex

[5] Point to Multipoint

[6] Point to Point

2 Market challenges

This section examines the market challenges facing three distinct groups of operators:

- B2B[7] backbone and access operators with a mix of wired and wireless networks
- MNOs[8] with a mix of wired and wireless backhaul
- B2C[9] broadband operators focused on delivering access solutions

2.1 B2B backbone and access operators

B2B backbone and access operators vary in their scale and capabilities. They include large operators that are able to offer a global communications solution to multinational enterprise customers. Operators will often use a blend of technologies (fixed and wireless) to provide the most appropriate and cost effective communications solutions for their business (both enterprise and other telecommunications service providers) customers and, in addition to the physical links, a service wrapper will typically be provided comprising of an SLA[10], network design, support and fault management.

Conventional circuit-switched technologies become less cost effective in terms of providing the network capacity required as demand for bandwidth hungry services increases. Fortunately service providers have found a cost effective, efficient and scalable solution in IP and Ethernet based technology which can reduce CAPEX and OPEX while minimising TCO[11]. B2B backbone and access operators are moving to IP and Ethernet based services from SDH/ATM (Synchronous Digital Hierarchy/Asynchronous Transfer Mode). IP/Ethernet networks can deliver efficiencies as multiple services (many of which are IP based) are offered across shared infrastructure. This allows service providers to roll out services much more quickly.

Depending on their existing network deployment a number of options are available to service providers as they migrate to IP/Ethernet networks. They might, for example, retain their existing legacy network and build a packet based overlay; replace the legacy network with a packet based IP network from the point of access to the core, or alternatively they might retain their legacy network and migrate to an IP/Ethernet network for access and aggregation to the network core.

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[7] Business to Business

[8] Mobile Network Operators

[9] Business to Consumer

[10] Service Level Agreement

[11] Total Cost of Ownership

However, while there are compelling arguments in favour of IP/Ethernet networks it is necessary to sound a note of caution. The roots of IP/Ethernet are in IT rather than telecoms and service managers will have to manage their networks carefully to avoid packet loss, latency and jitter.

The vast majority of IP connections are asymmetrical, that is the downstream rate is faster than the upstream rate. This arrangement is perfectly suitable for most IP applications but will not do for some, mainly business, applications. Examples include the exchange of large data files between offices (e.g. graphics, video, photographs and X-rays), VoIP (Voice over IP), website hosting, SaaS (Software as a Service) and multimedia streaming. Enterprises running these types of applications will benefit from symmetrical connections where the uplink is as important as the downlink. Symmetrical connections are available with fibre and SDSL (Symmetrical Digital Subscriber Line) but these solutions can be expensive.

In an enterprise environment, VoIP significantly reduces long distance telephone charges by transporting all long distance voice data over the Internet connection. It also provides a means for rich multimedia applications converging video, voice and data in a single session. Since VoIP shares the Internet connection with other forms of traffic, it must compete with other applications for network bandwidth and in order to make VoIP a viable business application in this scenario, its quality must be at least equal to traditional PSTN/ISDN voice and video services.

Streaming applications like VoIP and videoconferencing require performance guarantees to ensure that they do not suffer from bandwidth contention from less critical applications (e.g. non-critical Web browsing, large FTP file transfers, and P2P uploading/downloading of digital music and video files). Ensuring that the enterprise network has sufficient bandwidth, including provision for future expansion, together with a policy based Quality of Service (QoS) solution will safeguard the performance of business-critical voice and video applications.

Enterprises are frequently on the move. In the current economic environment, offices, shops and other commercial premises close down, while others are relocated and new ones are opened up. The deployment of a wireless solution avoids the high installation costs associated with fibre and can provide operators with a fast time to market, cost effective and flexible solution to provisioning services. However, the wireless solution must be cost effective, high capacity, flexible, and must support IP/Ethernet seamlessly.

2.2 MNOs with a mix of wired and wireless backhaul

In recent years MNOs have introduced new data services as voice services have matured and ARPU[12] has started to decline. SMS[13] was the first service to gain mass consumer acceptance and its introduction has greatly increased customer demand for data services. Encouraged by SMS's success, operators have introduced a whole host of new data services such as Internet access, sharing of photographs, music

[12] Average Revenue Per User

[13] Short Messaging Service

downloads, video calls, social networking, IPTV and games. The emergence of compelling data applications has occurred hand-in-hand with the appearance of smartphones, most notably the Apple iPhone and phones using Google's Android operating system. In addition there has been a proliferation of netbooks with USB wireless broadband modems adding further to the volume of data traffic across the mobile networks.

Driven by the take up of new mobile data devices coupled with increasing mobile penetration, mobile network data traffic has risen dramatically. In Figure 2-1, we can see that leading operators are meeting this surging demand for mobile data using HSPA, LTE and WiMAX networks. For example, on TeliaSonera's LTE network, the average monthly consumption is 14GB per month. This is several times more than the current typical MNO data plan (Vodafone UK typically offers 3-5GB per month) and indicates what MNOs will have to dimension their networks to support in the near future. By the end of 2010, 147 operators had confirmed their intention to adopt LTE, with eleven LTE networks already in commercial operation[14] to meet the surging demand for mobile data.

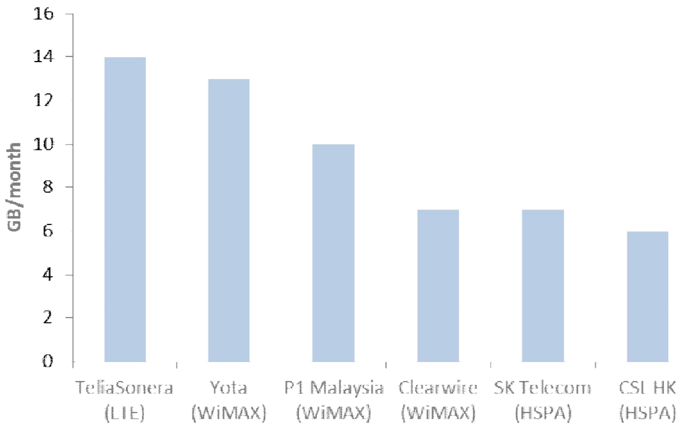


Figure 2-1 Monthly average data consumption for leading HSPA and WiMAX operators (Source: Operator data)

Rising mobile data consumption is having a knock on effect on the backhaul networks of MNOs. Unfortunately for MNOs the revenue per bit derived from data services is significantly lower than that from voice services so operators are looking closely at reducing the cost per bit of backhauling data traffic.

[14] Maravedis: A practical look at LTE backhaul requirements (Jan 2011)

As operators have moved from 2G to 2.5G and on to 3G and emerging LTE networks, different backhaul solutions have evolved. The typical model for 2G networks has been to use leased lines or Point to Point (PTP) microwave to carry TDM (Time Division Multiplexing) voice traffic from BTSs (Base Transceiver Stations) to BSCs (Base Station Controllers). In a similar way 3G networks use leased lines or microwave to provide ATM (Asynchronous Transfer Mode) backhaul between the Node Bs (equivalent of BTS) and the (RNC) Radio Network Controller.

The costs of these backhaul communications links can be high and account for a high percentage of a mobile network operator's OPEX. Nevertheless in the past the incremental backhaul costs have been offset by incremental revenue. MNOs see their backhaul network as a key strategic asset and backhaul optimisation is an increasingly important part of the business case for 3G/4G/WiMAX/LTE deployments.

Operators have typically used different backhaul technologies for their various RANs (Radio Access Networks). However, a unified IP backhaul that can be applied to all backhaul architectures can bring management and costs benefits. Later in this paper we look at how a TDD Point to Multipoint (PTMP) wireless solution can provide a cost effective and flexible backhaul solution.

2.3 B2C broadband operators focused on delivering access solutions

The rapid growth in the penetration of broadband in the home and the consequent increase in connectivity, has led to fundamental changes in the way many of us live our lives. Consumer demand for broadband, both fixed and mobile, continues to rise relentlessly and broadband speeds get ever faster to satisfy customers wanting to enjoy bandwidth-hungry applications such as Web 2.0 applications (podcasting, blogging, social networking, photo and video sharing etc.), music downloading, video-on-demand, HDTV[15], and multi-player gaming.

However, not everyone is able to share the myriad benefits that broadband can offer. The term *digital divide* refers to the gap between people with effective access to broadband and those with no access. This gap can be explained for reasons of income, skills, other social factors or location. This divide exists both within and between countries (see Figure 2-2 below[16]).

[15] High Definition TV

[16] OECD Broadband statistics - oecd.org/sti/ict/broadband

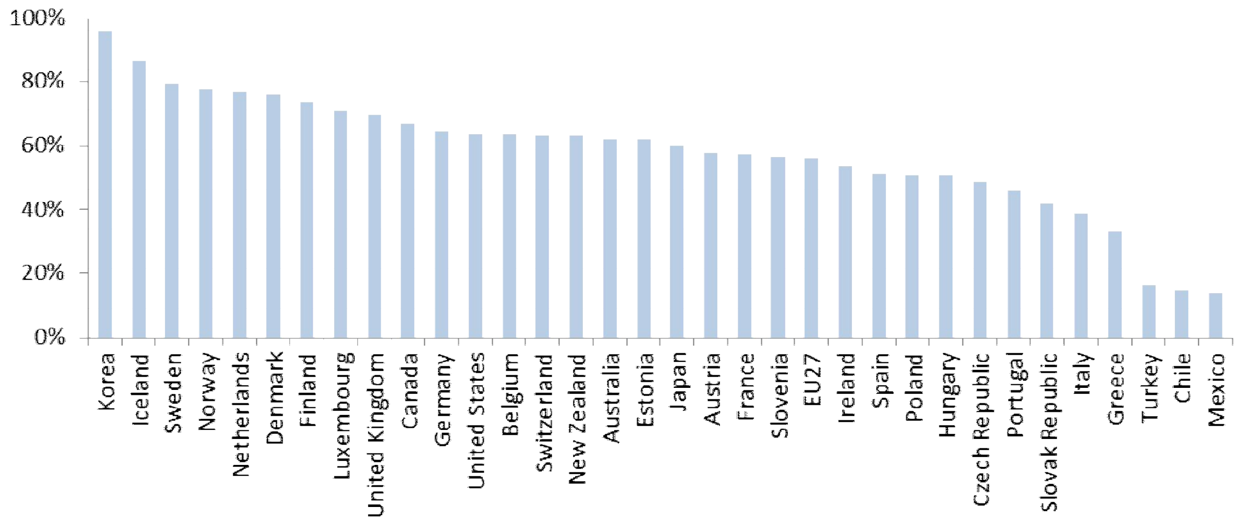


Figure 2-2 Percentage of households with broadband access (Source: OECD June 2010)

The *digital divide* has become a key issue for national and local authorities. The issue is particularly acute in less developed parts of the world where only a small minority of households have access to broadband. In India, for example, less than 0.5% of citizens are connected to broadband.

There is a general consensus among Europe's public authorities that access to the Internet should be a basic right, and that citizens should have access to its infrastructure and benefits. Switzerland was the first country to issue a USO (Universal Service Obligation) when in 2008 it ordered Swisscom to provide broadband at a regulated price. The Swiss Communications Markets Act, requires service providers that are subject to a USO to provide broadband at a minimum of 1 Mbps from July 2010. The Act represents the first step in a programme to make 100 Mbps broadband universal by the end of 2015. The EU has set itself the ambitious target of making the provision of broadband compulsory across the EU by 2013 with European households having access to at least 30 Mbps, and 50% or more of households having broadband subscriptions above 100 Mbps by 2020[17].

The EU recognises that substantial investment will be required to meet its ambitious penetration targets. It quotes up to €58Bn to achieve the 30 Mbps target and up to €268Bn to provide sufficient coverage so that 50% of households are on 100 Mbps services by 2020, using a mix of VDSL (Very High Bitrate DSL) and next generation wireless technologies. To ease the financial burden on individual nation states, in 2011 the EU will make a proposal for broadband financing including the use of EU funds.

Wireless infrastructure plays a key role in the EU's broadband coverage target and one of its key priorities is to make radio spectrum available for broadband service providers. Specifically it would like to see new spectrum being made available (such as 2.6 GHz and 800 MHz) and the liberalisation use of existing

[17] http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf

spectrum (e.g. the 900 and 1800 MHz band). Moreover, the ECC (Electronic Communication Committee) which acts as an expert on spectrum matters for CEPT (European Conference of Postal & Telecommunications Administrations) and the EU is targeting spectrum above 42 GHz for harmonisation and release[18] in support of the EU's Digital Agenda[19].

In the USA in July 2009, in response to a Congressional directive as to whether broadband "is being deployed to all Americans in a reasonable and timely fashion", the FCC (Federal Communications Commission) concluded that between 14M and 24M Americans lack access to broadband, and the immediate prospects for deployment to them are bleak. The report concludes that the goal of universal availability of advanced telecommunications, as set out in the 1996 Telecommunications Act, is not being met in a timely way. The FCC redefined broadband speed to 4 Mbps and addressed a number of key recommendations made in its own National Broadband Plan, including freeing up spectrum for mobile broadband.

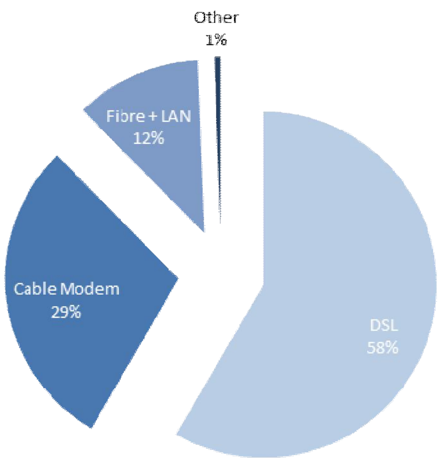


Figure 2-3 Fixed broadband subscriptions by technology (Source: OECD June 2010)

A wide range of technologies is available for fixed (i.e. not mobile) broadband access. However, as can be seen from Figure 2-3, the market (OECD countries) is dominated by DSL, followed by cable and fibre.

[18] Strategic Plan of the Electronic Communication Committee – Montpellier, France (March 2010)

[19] http://ec.europa.eu/europe2020/pdf/digital-agenda-communication-en.pdf

Other technologies include wireless, satellite and power line Internet. Figures from the EU[20] show a similar pattern with 78% of all broadband lines being DSL and cable modem accounting for 16%.

The cost of providing fibre or DSL to sparsely populated remote areas is likely to be prohibitive so service providers are of necessity looking at wireless solutions in order to meet their USO. Wireless PTMP solutions offer not only a valuable method of providing broadband service to rural areas in developed countries, they also have a key role to play in emerging markets where they can bring broadband to customers who have no existing fixed communications infrastructure.

Emerging countries face a number of challenges as they attempt to increase connectivity. Availability of fixed line infrastructure is limited, international Internet bandwidth is expensive, telecoms devices and computers are costly relative to income levels and there is a shortage of local experienced individuals and organisations to bridge the *digital divide*.

Many developing countries have been formulating national broadband strategies presenting their visions and service goals and from these strategies, policies and regulations have been developed to roll out broadband through public-private partnerships. The countries that have relied on competition on the provider side to expand the market have been the more successful ones and there has often also been a benefit from inter-modal competition, notably between DSL (Digital Subscriber Line), cable modem, and wireless technologies.

A number of steps can be taken to boost the availability of broadband in developing countries. On the demand side governments can raise awareness of broadband and promote its use, subsidise devices and terminals and develop and support local content. On the supply side they can actively support new entrants to expand the market, provide government support for national backbone construction, remove regulatory barriers, reduce providers' investment costs and use spectrum frequency policies to facilitate wireless services.

A key advantage of wireless networks is their ability to extend broadband access to rural areas beyond the reach of ADSL and cables. Networks can be rolled out at relatively low cost to areas with low population densities, challenging topology and a lack of basic infrastructure such as roads and electricity supply. Furthermore the scalability of wireless networks means they can easily be expanded to support increasing bandwidth needs. Wireless networks clearly have a key role to play in broadband market development and telecoms regulators need to encourage growth of these networks through spectrum release especially at higher frequencies above 3 GHz.

[20] http://ec.europa.eu/information_society/policy/ecomm/doc/implementation_enforcement/annualreports/factsheets/broadband.pdf

3 Spectrum overview

Spectrum is a scarce resource and must be used efficiently and appropriately i.e. the right spectrum for the right application. In recent years the focus of regulators has been to release what is considered to be prime mobile spectrum i.e. below 3 GHz. However, there is limited amount of spectrum below 3 GHz where the MNOs have dominated spectrum ownership and have delivered mass market mobile voice and data services. Consequently the price of such spectrum is high and as demand for spectrum for services such as mobile data continues to rise, spectrum pricing below 3 GHz will remain high. Recently, regulators have started to assess innovative technologies such as cognitive radio which can utilise the "white spaces" or fragmented blocks between occupied bands of spectrum.

The broad market dynamics which we discussed in section 2 of this paper, demand a solution which can deliver a fixed wireless high capacity services over appropriate spectrum bands. In summary, these market dynamics are:

- Increasing mobile data demand and consequent increasing demand for MNO backhaul
- Increasing and flexible capacity requirements by enterprises
- Universal Service Obligation for broadband in difficult to reach geographies
- Flexible and high capacity solution for consumer broadband and voice in emerging markets

In the sections below we discuss how TDD PTMP based solutions utilising higher bands above 3 GHz are ideal for delivering high capacity, cost effective fixed solutions for MNO backhaul and enterprise and consumer access.

3.1 Why wide channels?

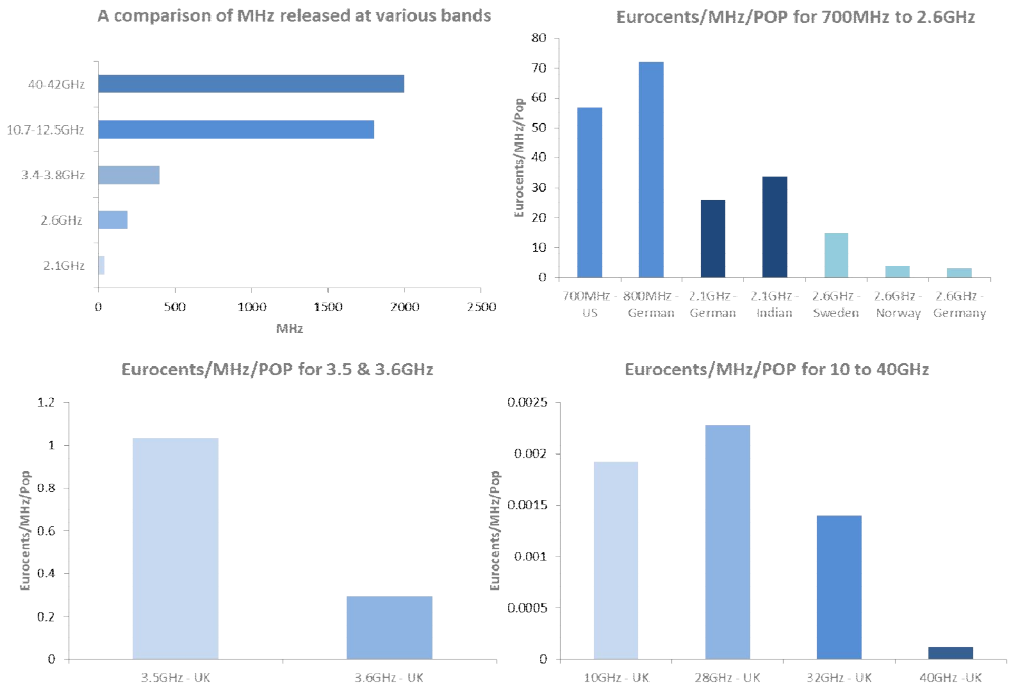
In 1948, Claude Shannon, an American mathematician and engineer, whilst working at Bell Labs published a landmark book (*A Mathematical Theory of Communication*) which laid the foundations of modern information and communications theory. Shannon asserted that the amount of error-free data that could be transmitted over a channel of any given bandwidth was limited by noise. While increasingly efficient technologies can be developed, there is a ceiling at which any gains of capacity are cancelled out by noise. This fundamental limit has become known as Shannon's Law.

Shannon's Law is particularly pertinent in the wireless world where spectrum is scarce. Engineering innovations have constantly pushed the limits of what can be delivered in terms of bits per second per Hertz (i.e. the amount of information in any given unit of spectrum), by decreasing noise in the channel.

Today modern radio technology is reaching the spectral efficiency limits set by Shannon's Law and as a consequence one of the key ways forward beyond engineering solutions like smart antenna technologies, for the delivery of high capacity, is the harnessing of wider spectrum channels.

However, to find clear blocks of spectrum that can support wide channels is a challenge for regulators and consequently for operators. Spectrum below 3 GHz has the range and penetration capabilities (i.e. through walls) which is ideal for mass consumer services and therefore such spectrum is highly prized by

MNOs and TV broadcasters as well as for use with unlicensed technologies such as Wi-Fi in the ISM[21] 2.4 GHz bands.



Notes:

- Values for 700 MHz US taken from auction in 2008
- Values for 800 and 2.6 GHz German auction taken from 2010
- Values for 2.6 GHz Indian auction taken from 2010
- Values for 3.5 GHz UK taken from auction in 2003
- Values for 3.6 GHz UK taken from PCCW acquisition in 2010
- Values for 10-42 GHz UK taken from auction in 2008

Figure 3-1 Spectrum availability and pricing (Eurocents/ MHz/Pop)

In Figure 3-1, we see a comparison of various spectrum bands in particular the amount of spectrum released by regulators for commercial use and the prices paid by operators at recent auctions and through M&A[22]. The charts illustrate the following key points:

- Scarcity of spectrum is particularly acute below 3 GHz

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[21] Industrial Scientific Medical

[22] Mergers and Acquisitions

- Higher bands such as 12 GHz[23] and 42 GHz[24] which are not contested by MNOs and TV services have large blocks of spectrum suitable for wide channels
- Recent auctions indicate that spectrum below 3 GHz is typically a factor of 100,000 times (on a Eurocents/ MHz/Pop basis) more expensive than bands such as 12 GHz and 42 GHz

There is an emerging picture of spectrum release and availability at bands such as 12 GHz and 42 GHz. The ITU WRC 2007[25] designates 10.7-12.5 GHz and the 42.5-43.5 GHz bands to fixed wireless services (i.e. PTP and PTMP) on a co-primary[26] basis. An increasing number of national regulators have adopted such recommendations as part of their national frequency plans e.g. Bahrain[27], Jordan[28] and Saudi Arabia[29].

Ofcom, the UK's converged telecoms and media regulator, has been at the vanguard of releasing large blocks of spectrum for commercial use and as such set a precedence for the release of substantial blocks of 12 GHz and 42 GHz through auction in 2008[30]. Similarly, the Malaysian regulator, SKMM, has in 2010 released 300 MHz of spectrum in the 12 GHz bands[31].

3.2 TDD versus FDD

Historically spectrum releases have adopted a band plan which facilitates Frequency Division Duplexing (FDD) as opposed to Time Division Duplex (TDD). In FDD systems uplink (UL) and downlink (DL) transmissions are allocated separate bands. The UL and DL are grouped in to contiguous blocks of paired channels as shown in Figure 3-2 and separated by a guard band.

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[23] When we mention 12 GHz we are referring to the 10.7-12.5 GHz range which is recommended for fixed wireless services on a co-primary basis by the ITU WRC 2007

[24] When we mention 42 GHz we are referring to the 40.5-43.5 GHz range which is recommended for fixed wireless services on a co-primary basis by the ITU WRC 2007

[25] The International Telecommunications Union (ITU) is an agency of the United Nations. The ITU coordinates shared global use of spectrum and at its 5 yearly World Radio communications Conference (WRC) makes recommendations on radio spectrum usage. The last WRC took place in 2007 and is referred to as WRC-2007.

[26] Co-primary means spectrum is shared between different types of application e.g. fixed wireless and satellite

[27] www.tra.org.bh/en/pdf/KingdomOfBahrainNationalFrequencyPlanFianl.pdf

[28] www.trc.gov.jo/images/stories/pdf/NationalTableofFrequencyAllocationsofJordan.pdf?lang=english

[29] www.citc.gov.sa/NR/rdonlyres/8BC3B6CF-44D0-4BE1-8611-735C9121490F/0/NFPVer9September.pdf

[30] http://stakeholders.ofcom.org.uk/binaries/consultations/10-42GHz/statement/statement.pdf

[31] www.skmm.gov.my/images/pdf/FWA.pdf

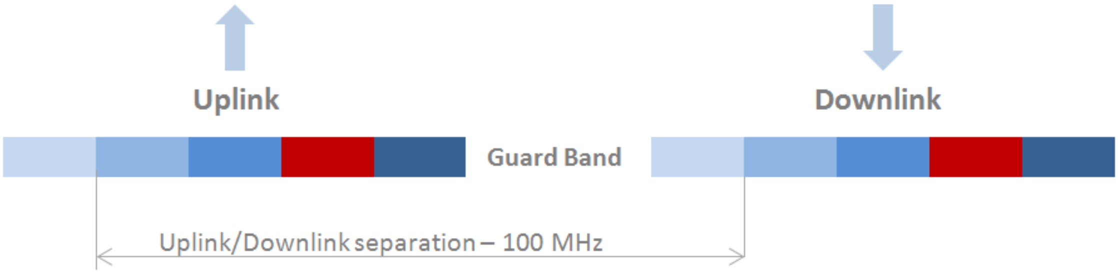


Figure 3-2 FDD band plan showing uplink and downlink blocks separated by a guard band

The paired UL and DL channels are typically separated by a 100 MHz. This separation between UL and DL and the guard band minimises the interference of one FDD system and another.

FDD systems provide full duplex operation making them ideal for applications such as voice where UL and DL traffic is symmetrical. The large separation between UL and DL means that the interference between base stations or between subscriber units (e.g. handsets) is minimised. This is particularly relevant for mobile systems where handsets move from one place to another and can be in close proximity with other handsets. The downside of FDD systems is that it can result in inefficient use of spectrum because of the requirement for a guard band. Moreover, FDD is inflexible for asymmetric data services in a data centric world where UL and DL bandwidth requirements are constantly changing and operators want the flexibility of dynamic provisioning to meet customer demands.

FDD systems also have a hardware disadvantage in that they require complex costly RF (Radio Frequency) filters to isolate the UL and DL channels. For fixed wireless data services i.e. non mobile systems, TDD has significant advantages over FDD. A TDD system does not require paired UL and DL channels and does not require a guard band. TDD systems use the same channel for UL and DL transmission separating them in the time domain as shown in Figure 3-3.

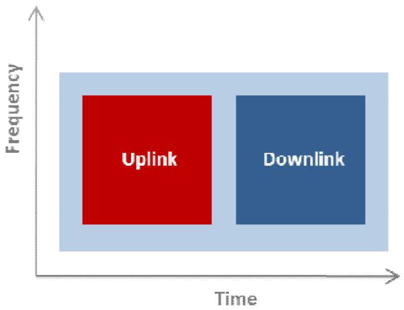


Figure 3-3 TDD system where uplink and downlink operate in the same frequency block but are separated in time

TDD systems can flexibly allocate bandwidth for UL and DL depending on the service proposition requirements of the operator. Moreover, there is no requirement for complex RF filters to (effect separation between UL and DL) which can add significant cost to an operators' business case.

Issue	TDD	FDD
Need for guard band to separate UL and DL	No requirement	Required to separate UL from DL and is less efficient use of spectrum
Dynamic bandwidth allocation	Adaptive UL/DL allocation allows dynamic bandwidth allocation for UL and DL traffic	UL/DL allocation cannot be modified. This leads to unused spectrum for asymmetric operations and inflexibility in services that can be delivered
Need for RF filters	No requirement	Required to prevent interference across UL and DL channels
Hardware cost	Transmitter and receiver operate on the same frequency but at different times so hardware elements are reused and costs reduced	Hardware requires spatial separation and cannot be reused. This results in higher costs

Figure 3-4 Summary of the benefits of TDD versus FDD

In summary (see Figure 3-4), TDD is the more desirable duplexing technology for data orientated fixed wireless services allowing operators to maximise their investment in spectrum and telecom equipment, while meeting the needs of individual customers.

3.3 The advantages of a TDD PTMP solution

We discussed earlier that the efficient way to deliver high capacity fixed wireless data services is to deploy large blocks of contiguous spectrum and that such blocks of spectrum are increasingly available at cost effective price points at higher bands such as 12 GHz and 42 GHz. We then discussed why TDD can be the best way to leverage such wide blocks of spectrum to deliver high capacity fixed wireless data services.

In the next section we discuss why using a PTMP architecture can effectively harness wide TDD channels and provide operators with the optimal business case by:

- Efficiently managing scarce spectrum resources
- Dynamic allocation of capacity amongst subscribers
- Providing a flexible network architecture which lends itself to rapid subscriber acquisition

4 A comparison of PTMP and PTP solutions

In section 3 we discussed how operators can deliver high capacity fixed wireless data services using wide channel TDD spectrum at higher bands such as 12 GHz and 42 GHz. In this section, we discuss how such TDD systems are deployed in a PTMP architecture to achieve the optimal business case for operators.

4.1 An example network

Consider a hypothetical network as shown in Figure 4-1, where a Point of Presence (PoP) connected to a backbone feeds *n* endpoints via a wireless PTMP or a PTP architecture. In a PTP architecture, *n* endpoints require n times dedicated PTP link. Compare this to a PTMP architecture which can service *n* endpoints via a central PTMP base station and lower cost subscriber units at the endpoints.

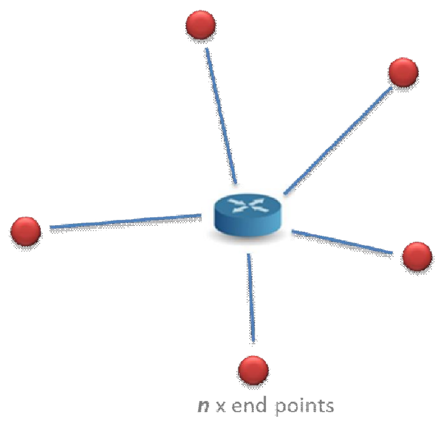


Figure 4-1 A hypothetical network with *n* endpoints being serviced from a central Point of Presence

As a consequence of not requiring dedicated *n* links to serve *n* endpoints, a PTMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. This provides for a flexible network topology which lends itself to subscriber adds, moves and changes thus lowering OPEX for an operator and facilitating rapid subscriber acquisition. In the next section, we use this hypothetical network to assess the comparative CAPEX and OPEX.

4.2 CAPEX and OPEX drivers

Let's consider each of the major CAPEX and OPEX drivers for an operator looking to deliver high capacity fixed data services using PTMP and PTP systems. Our analysis refers back to the hypothetical network in Figure 4-1.

4.2.1 Radio masthead and subscriber unit costs

A traditional PTP microwave architecture requires large antenna dishes at each end of a link. Hence, in the network example of Figure 4-1, a PTP system would require 2*n* radio mastheads. In a PTMP solution, on other hand, the central PTMP base station serves simpler and less costly subscriber units which are placed at the endpoints. Hence:

(2*n* x PTP radio mast head) cost > (PTMP base station + *n* x subscriber units) cost

4.2.2 Installation costs

Installing radio mast heads is costly and a PTP solution requires 2n radio masts as compared to a PTMP solution which requires a single base station and simpler subscriber units at the endpoints.

4.2.3 Planning applications

Visual impact has become a sensitive subject and putting up large numbers of radio antenna dishes is not acceptable in many environments. Traditional PTP solutions require dedicated radio mast heads at each end of a radio link. In certain geographies this can require a planning application for each radio mast head, which is not only a costly exercise but also time consuming. A PTMP solution with simpler subscriber units simplifies and reduces the cost of the planning process.

4.2.4 Site rental

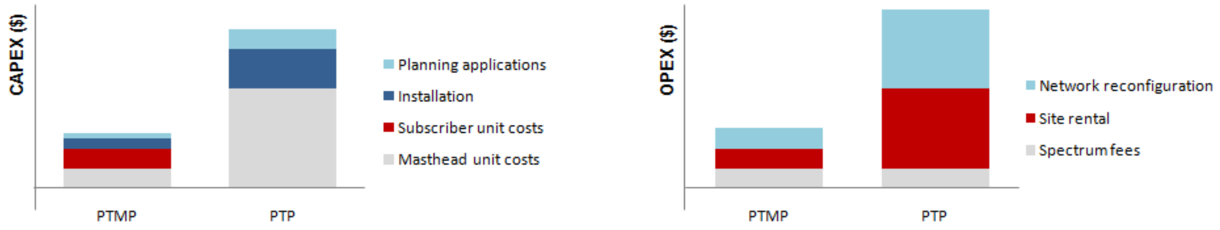
Tower operators and owners of prime real estate have benefited from the success of mobile voice and data and increasing site rental costs have become significant OPEX element of an operators' business case. With simpler subscriber units, a PTMP solution can significantly reduce site rental costs compared with PTP architectures.

4.2.5 Spectrum fees

A PTMP architecture can efficiently manage scarce spectrum resources as it can dynamically allocate capacity amongst *n* endpoints. With PTP, an operator is forced to dedicate spectrum to each link which can be inflexible and can typically be more expensive in terms of spectrum fees as you may pay for spectrum on a per link basis. In our comparison of PTMP and PTP CAPEX and OPEX in the next section, for simplicity we have assumed spectrum fees are identical for the two cases.

4.3 A comparison of PTMP and PTP CAPEX and OPEX

In Figure 4-2, we present a macro level view of the CAPEX and OPEX for PTMP and PTP architectures based on the hypothetical network in Figure 4-1. The comparison is simplistic but it helps clarify the key cost drivers and how a PTMP solution can be a more cost-effective solution for operators looking to deliver high capacity fixed wireless data services at a low TCO. A PTMP solution when combined with large blocks of contiguous TDD spectrum available at higher bands such as 12 GHz and 42 GHz, can deliver a cost effective, flexible and high capacity wireless solution. In section 5 we introduce Bluwan's FTTA TDD PTMP solution for access and backhaul applications.



Notes:

- We have assumed that a PTP solution requires masthead units at each end of a radio link whilst a PTMP solution uses a simpler subscriber unit at the subscriber end
- For simplicity masthead unit costs are identical for PTMP and PTP
- Subscriber unit cost for a PTMP solution is 20% of a masthead unit cost
- Installation cost for PTMP is 25% of PTP for the example network
- Planning application costs for PTMP is 25% of PTP for the example network
- For simplicity spectrum fees are identical for PTMP and PTP
- Site rental and network reconfiguration for PTMP are 25% of PTP for the example network

Figure 4-2 High level comparison of CAPEX and OPEX for PTMP and PTP architectures

5 Key operator requirements and the Bluwan solution

In section 2 we discussed the market challenges faced by three different operator categories:

- B2B operator delivering high capacity data services to enterprise customers
- MNOs requiring cost-effective high capacity backhaul to 3G/HSPA/WiMAX/LTE base stations
- B2C broadband operator

On the face of it these operators have very different business models. However, there are some key common requirements across each of these operator categories. In the sections below we firstly examine how different technologies (including TDD PTMP) compare with regard to the key operator requirements and then we introduce the Bluwan TDD PTMP architecture.

5.1 Comparing TDD PTMP with other solutions

The key common requirements that run across our operator categories are the need for:

- High data capacity
- Flexibility in uplink and downlink i.e. support of asymmetrical and symmetrical services
- Support for IP and Ethernet with low jitter and latency
- Support for voice, video and data services
- Ease of network reconfiguration facilitating network adds, moves and changes
- Rapid provisioning of new services
- Rapid customer acquisition
- Low TCO in terms of CAPEX and OPEX that enables operators to build a robust business case and maximises the revenue per bit whilst minimising the cost per bit

In sections 3 and 4 we looked at how high capacity data services can be delivered using fixed wireless TDD PTMP solutions harnessing large contiguous spectrum blocks at higher bands such as 12 GHz and 42 GHz. In Figure 5-1 below, we compare such a fixed wireless TDD PTMP solutions with xDSL, Microwave PTP, Fibre and Leased Lines in terms of the key common requirements listed above.

Operator requirements	xDSL	Microwave PTP	Fibre	Leased Line	FTTA TDD PTMP
High data capacity	◔	◐	●	◕	●
Flexibility in uplink and downlink	○	●	●	●	●
Support for IP and Ethernet	●	●	●	●	●
Support for voice, video and data	●	●	●	●	●
Rapid provisioning of new services	●	●	●	●	●
Easy adds, moves & changes	○	○	○	○	●
Rapid customer acquisition	○	○	○	○	●
Low TCO	◑	◑	○	◑	●

Figure 5-1 Benchmarking TDD PTMP wireless versus other technologies

5.2 FTTA: The Bluwan TDD PTMP solution

From Figure 5-1 we can conclude that a TDD PTMP wireless based technology has certain key advantages over rival technologies when it comes to delivering flexible, high capacity and low TCO data services. Fibre Through The Air (FTTA) is Bluwan's gigabit wireless network technology based on TDD PTMP technology at 12 GHz and 42 GHz. The FTTA architecture is easily extendable using relay nodes and harnesses the cost-effective large contiguous spectrum blocks available at higher frequencies which we discussed in section 3. FTTA's use of low power transmitters and high directivity antennas enable a high degree of frequency reuse, delivering very large amounts of capacity in a given area. FTTA's architecture makes it ideal for solving the challenges faced by our three operator cases.

5.2.1 FTTA for B2B operators

FTTA is compact and easy to deploy using a PTMP topology which enables operators to rapidly deploy and deliver flexible uplink and downlink high capacity data services. FTTA can deliver gigabit speeds using IP and Ethernet interfaces comparable to fibre but at a much lower cost and without the time and disruption required for laying fibre.

5.2.2 FTTA for MNO backhaul

FTTA provides a robust backhaul solution for MNOs integrating seamlessly with 3G, HSPA, WiMAX and LTE base stations. FTTA links multiple base station to provide a vastly superior download capacity when compared to legacy PTP microwave, allowing MNOs to address increasing mobile data consumption and supporting multimedia applications such as video streaming.

FTTA is more compact, easier to deploy (because of its PTMP architecture) and as we discussed in section 4, more cost effective in terms of CAPEX and OPEX when compared to traditional PTP microwave solutions.

5.2.3 FTTA for B2C operators

For a B2C operator, FTTA presents a compelling value proposition not only for difficult to reach geographies (for example as part of broadband USO) but also a platform for delivering multiple play (i.e. voice, broadband and TV) at a lower cost of deployment than ADSL2+. FTTA can be deployed directly to Multiple Dwelling Units (MDU) and individual households. For individual households, the distribution typically happens through standard coaxial TV cable. In the case of MDUs, FTTA supports integration with copper lines, coaxial cables and Ethernet over powerline.

The FTTA access solution for B2C operators uses small form factor outdoor subscriber units and a Bluwan home residential gateway.

5.3 Overview of FTTA architecture

The FTTA solution is a hierarchical, PTMP multi gigabit wireless wide area network. The solution is architected as a distribution tree connecting a service provider's PoP to relay nodes and ultimately reaching:

- Subscriber terminals (consumer or enterprise)
- Grouped terminals (such as those found on top of MDUs)
- Mobile base stations (for MNO backhaul)

From the PoP, each FTTA area served is supported by ultra wide band radios configured for PTMP. These areas are served by a spectrum bandwidth ranging from 250 MHz to 1 GHz (in the 12 GHz or 42 GHz bands) depending on the operator's spectrum licence. These wide band radios can transport a multiplex of waveforms which are adapted to the services and capacity required for the operator's customers. A diverse set of antennas provided by Bluwan is leveraged to deploy a network tailored to the topology of the area. Typical link capacity is up to 130 Mbps which can either be dedicated to MNO backhaul or shared in the case of access solutions for consumers and enterprises. FTTA uses standard interfaces which are seamlessly integrated to an operator's existing network and services. Adding a FTTA solution to an operator's network improves capacity and throughput without requiring a change to existing services. FTTA is fully modular and can increase capacity and coverage as the operator's needs evolve.

In summary:

- FTTA can deliver of high capacity data services by harnessing large blocks of cost effective TDD spectrum in ultra wide channels available at higher bands such as 12 GHz and 42 GHz
- FTTA offers a highly flexible PTMP network topology which can rapidly adapt to an operator's coverage and capacity requirements

- The cost of FTTA is significantly less than laying fibre and compared to a consumer Fibre to the Home (FTTH) proposition can offer a per subscriber cost saving of up to 10x
- The FTTA PTMP architecture offers a modular solution that can scale with an operator's requirements as well as being more cost effective than a PTP solution in terms of both CAPEX and OPEX
- FTTA enables B2C operators to offer multiple play services to consumers and thereby significantly increase ARPU and reduce customer churn

6 Glossary

3G 3G is the third generation of standards for mobile phones and services specified by the International Telecommunication Union. Application services include wide area wireless voice telephone, mobile internet access, video calls and mobile TV.

4G 4G stands for the fourth generation of cellular wireless standards and is the successor to 3G standards. Speed requirements for 4G service set the peak download speed at 100 Mbps for high mobility communication and 1 Gbps for low mobility communication. 4G systems provide all-IP based mobile broadband solutions to mobile devices.

ADSL2+ ADSL2+ stands for Asymmetric Digital Subscriber Line. It extends the capability of basic ADSL by doubling the number of downstream bits.

ATM ATM stands for Asynchronous Transfer Mode. It is a switching technique for telecommunication networks that uses asynchronous time-division multiplexing and it encodes data into small, fixed-sized cells.

BSC BSC stands for Base Station Controller. It provides the *intelligence* behind the BTS (Base transceiver Station). Typically a BSC has tens or even hundreds of BTSs under its control. The BSC handles allocation of radio channels, receives measurements from the mobile phones, and controls handovers from BTS to BTS.

BTS BTS stands for Base Transceiver Station. It contains the equipment that facilitates wireless communication between user equipment and a network.

Channel Channel refers to one of a number of discrete frequency ranges utilised by a base station to transmit and receive information from mobile devices.

DSL DSL stands for Digital Subscriber Line. DSL is a family of technologies that provide digital data transmission over the wires of a local telephone network. DSL service is delivered simultaneously with regular telephone on the same telephone line.

DVB-S2 DVB-S2 or Digital Video Broadcasting Satellite Second Generation is the successor to the DVB-S digital television broadcast standard.

EHF EHF stands for Extremely High Frequency. Frequencies are in the 30 GHz to 300 GHz range.

Ethernet Ethernet is a family of frame-based computer networking technologies for local area networks (LAN).

FDD FDD stands for Frequency Division Duplex. In fixed wireless PTMP systems that use FDD, one frequency channel is transmitted downstream from a base station to a fixed subscriber terminal (downlink) and a second frequency is used in the upstream direction (uplink).

FTTA FTTA stands for Fibre Through The Air. It is the name for Bluwan's PTMP gigabit wireless network.

FTTH FTTH stands for Fibre To The Home. FTTH reaches the boundary of the living space, such as the box on the outside wall.

FTP FTP stands for File Transfer Protocol. It is a standard network protocol used to copy a file from one host to another over a TCP (Transmission Control Protocol) based network, such as the Internet.

HDTV HDTV stands for High Definition Television. It refers to video resolution substantially higher than traditional television.

HSDPA HSDPA stands for High Speed Downlink Packet Access. It is a 3G protocol in the HSPA family. HSDPA allows networks to have higher downlink data transfer speeds and capacity.

HSPA HSPA stands for High Speed Packet Access. It is an amalgamation of two mobile telephony protocols, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA). A further standard, HSPA+, supports significantly higher data rates.

HSUPA HSUPA stands for High Speed Uplink Packet Access. It is a 3G protocol in the HSPA family. HSUPA improves the performance of uplink dedicated transport channels.

IP IP stands for Internet Protocol. It is responsible for addressing hosts and routing packets from a source host to the destination host across one or more IP networks.

IPTV IPTV is Internet Protocol Television. It is is a system through which television services are delivered using the architecture and networking methods of the Internet Protocol Suite over a packet-switched network infrastructure.

ISDN ISDN stands for Integrated Service Digital Network. It is a set of communications standards for simultaneous digital transmission of voice, video and data over the public switched telephone network.

ITU WRC2007 The International Telecommunication Union (ITU) approved the use of the 450-470 MHz frequency band for international mobile telecommunications technologies during the 2007 World Radiocommunication Conference (WRC-2007).

LTE LTE is 3GPP (3rd Generation Partnership Project) Long Term Evolution. It is the next generation network standard beyond 3G. In addition to enabling fixed to mobile migrations of internet applications such as VoIP, video streaming and music downloading, LTE networks will also provide the capacity to support consumer devices tailored to new mobile applications. The LTE specification provides downlink peak rates of at least 100 Mbps and an uplink of at least 50 Mbps.

Node B Node B is the hardware that is connected to the 3G mobile phone network that communicates directly with mobile handsets. The Node B is the equivalent to the BTS (Base Transceiver Station) used in GSM networks.

ODU ODU stands for Outdoor Unit i.e. a radio antenna.

P2P P2P stands for Peer to Peer. Compared to Web browsing or e-mail, where data is only transferred in short intervals and relative small quantities, P2P file-sharing often consists of relatively heavy bandwidth usage due to ongoing file transfers.

PTMP PTMP stands for Point to Multipoint. It provides multiple communication paths from a single location to multiple locations.

PoP PoP stands for Point of Presence. On the Internet, a PoP is an access point from one place to the rest of the Internet.

Pop Pop refers to the population within a mobile operator's licensed area.

PSTN PSTN stands for Public Switched Telephone Network. It delivers fixed telephone service.

PTP PTP stands for Point to Point. It provides a single communication path such as a microwave link.

QoS QoS stands for Quality of Service. It is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow.

RAN RAN stands for Radio Access Network. It is the part of the mobile telecommunications system that sits between the mobile phone and the core network.

RNC RNC stands for Radio Network Controller. It is the governing element in the 3G radio access network and is responsible for controlling the Node Bs that are connected to it.

SaaS SaaS stands for Software as a Service and is sometimes referred to as 'software on demand'. SaaS is software that is deployed over the internet.

SDH SDH stands for Synchronous Digital Hierarchy. These are standardised multiplexing protocols that transfer multiple digital bitstreams over optical fibre. SDH is well suited for transporting Asynchronous Transfer Mode (ATM) frames.

SDSL SDSL stands for Symmetric Digital Subscriber Line. This is a variation of DSL technology where the downstream and upstream data rates are equal.

SHF SHF stands for Super High Frequency. Frequencies are in the 3 GHz to 30 GHz range.

SMS SMS stands for Short Messaging Service. It is available on digital networks, typically enabling messages with up to 160 characters to be sent or received via the message centre of a network operator to a subscriber's mobile.

SNMP SNMP stands for Simple Network Management Protocol. It is an Internet standard protocol for managing devices on IP network such as routers, switches, servers, workstations, printers and modem racks. It is commonly used in network management systems.

TCPIP TCPIP stands for Transmission Control Protocol/Internet Protocol. It is the basic communication protocol of the Internet and can also be used as a protocol in a private network.

TDD TDD stands for Time Division Duplex. In fixed wireless PTMP systems that use TDD, a single frequency channel is used to transmit for the both the uplink and the downlink.

TDM TDM stands for Time Division Multiplexing. It is a type of (usually digital) multiplexing in which two or more signals are transferred apparently simultaneously as sub-channels in one communication channel, but are physically taking turns on the channel.

VoIP VoIP stands for Voice over Internet Protocol. It is any of a family of methodologies, communication protocols, and transmission technologies for delivery of voice communications and multimedia sessions over Internet Protocol (IP) networks, such as the Internet.

WAN WAN stands for Wide Area Network. A WANs is a computer network that covers a broad area and connects other networks together.

WiMAX WiMAX is a global wireless metropolitan area network standard. It operates at both licensed and unlicensed frequencies (2.5 GHz, 3.5 GHz and 5.8 GHz) and in PTP as well as PTMP configurations