

# Wireless Strategy For HEAnet Wireless Broadband Access Services

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# 1 Document control

## Revision and Signoff Sheet

### Document Control

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### Document Review

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### References:

1. Interim Report Wireless Strategy Options  
(20080123 HEAnet wireless strategy final.doc)
2. Final Report Wireless Strategy Options  
(20080221 HEAnet Report Wireless Strategy.doc)
3. Executive Summary - Wireless Strategy Options  
(Executive Summary Wireless Strategy.doc)

### 3 Background

There is an ever increasing demand for mobility both on and off campus by students and staff in the Higher Education sector. This demand is driven a number of factors including:

- a steady increase in laptop computer ownership and usage
- the increased adoption of other mobile data devices including PDAs notebooks and data enabled phones
- the facilitation of wireless data access both on-campus through the implementation and rollout of Wireless LAN and the rollout of higher bandwidth mobile technologies by commercial operators
- The increase in usage of portal access for learning, mail and other services offered by Higher Education Institutes.
- Increased expectations and demand for anywhere anytime access to campus network resources and services.

The Higher Education sector recognises the growing requirements of both Students and staff for mobile data access and access to the internet and campus network resources.

HEAnet employed the services of Ward solutions Ltd to investigate the possibility of providing nationally ubiquitous wireless access to the HEAnet network for all HEAnet clients. The subsequent report:

- identified all potential options in providing wireless access to the HEAnet network for all HEAnet clients
- Identified the most feasible and realistic of these options as practical candidates for implementation by HEAnet and Higher Education Institutes

## 4 Introduction

HEAnet is Ireland's National Education and Research Network, providing an extensive catalogue of service offerings to the Higher Education sector, including high quality Internet Services to over 150,000 students and staff in Irish Universities, Institutes of Technology and other educational and research organisations.

HEAnet and its staff are committed to delivering and supporting advanced network infrastructure and associated services in furtherance of national and international objectives for Irish education and research.

The current HEAnet network is built using dedicated fixed infrastructure to enable HEAnet clients to connect to the general Internet and to other education and research networks worldwide. Currently the HEAnet network does not provide any wireless services or access via wireless infrastructure to its customer base. While the majority of HEAnet clients have implemented their own local wireless networks, these networks are all standalone deployments and are not part of the HEAnet service offering.

The delivery of Mobile wireless access is seen as a key and critical component for HEAnet to fulfil its mission in delivering and supporting a world class service to the Higher Education community. HEAnet has recently undertaken a study to investigate the possibility of providing nationally ubiquitous wireless access to the HEAnet network for all HEAnet clients. This report was delivered in two parts:

- Part 1: (Interim Report) identified a suite of feasible options in providing wireless access to the HEAnet network for all HEAnet clients
- Part 2: further developed a limited number of these options on practical wireless broadband access services for HEAnet clients.

These reports were based on

- The current wireless environment in the Higher Education Sector
- Requirements gleaned through interviews with and feedback stakeholders
- Interviews with representatives of the International Higher Education and Research sector
- Interviews with wireless commercial operators
- Research into current technologies and future trends for wireless access technologies

### 4.1 HEAnet's Vision

HEAnet in cooperation with the Higher Education Institutes will establish ubiquitous wireless broadband access to the HEAnet network for all HEAnet clients. It is expected that any service will be nationally available and will enable a wireless user to authenticate against their home institution and seamlessly avail of all relevant services at the user's home institution, including general internet access.

### 4.2 Strategic Approach

HEAnet proposes a National strategy initiative spearheaded by HEAnet with the co-operation of the Higher Education Institutes in order to deliver countrywide mobile wireless broadband and wireless broadband access to the Higher Education user community. This document details HEAnet's strategy for the delivery of a wireless broadband access service for HEAnet's client community.

It complements HEAnet's Strategy for Delivering a world class network and services to its customers and adheres to HEAnet's business model which is *based on delivering economies of scale and enabling the delivery of advanced telecommunications services for its clients through centralised expertise.*

HEAnet intends to:

- Provide ubiquitous wireless access to the HEAnet network for all HEAnet clients.

- Deliver access that will cover the whole island of Ireland
- Enable a wireless user to authenticate against their home institution and seamlessly avail of all relevant services at the user's home institution, including general internet access.
- Leverage Eduroam as the primary means of authentication
- Ensure that the solutions implemented are flexible and extensible. That they are capable of offering new services and increased service and performance levels over time in order to meet the changing requirements of the Higher Education Community and the changing technologies used in their delivery.

## 5 The Environment

### 5.1 HEAnet Customer Base

HEAnet provides services to a wide diversity of Universities, Institutes, Colleges, Schools and other organisations including educational agencies. Individual Higher Education Institute profiles range from large city centre and city suburb based multi campus institutes with tens of thousands of users with large sophisticated IT services, infrastructure and staffing, to smaller city and town based Higher Education Institutes with hundreds of end users and much smaller staffing levels, including IT staffing levels. They vary widely in terms of the types of IT services offered both on and off campus and their respective policies towards their user communities – e.g. some Higher Education Institutes offering wireless access to the network and internet to everyone including general public. Other Higher Education Institutes have very restrictive access policies to the network and internet generally offering no wireless services and limited or practically no access to the Internet.

Overall HEAnet network service users primarily comprise 150,000 users spread across these higher Education Institutes and includes students, staff, researchers and guest users.

User profiles range widely in diversity from students attending Higher Education Institutes with varying degrees of student laptop penetration living almost permanently in relatively close proximity (<20KM) to the campus to highly transient user populations domicile in relatively close proximity to campus during the week and dispersing to a much more distant proximity (>20K to nationwide/international) to campus at weekends and during term breaks.

### 5.2 Current Network Services Provision

#### On Campus

Most Higher Education Institutions have an extensive mix of cabled Ethernet connections and are increasingly offering on-campus wireless services using WLAN/ WiFi (802.11) technology with access to both internal applications and services and to the Internet. A number of Higher Education Institutes offer Public/"Guest" network access to limited campus service and to the Internet. Generally network services provision are delivered and supported by the Higher Education Institutes IT department. Some recent initiatives have been made in the sector to construct peering and outsourcing arrangements for WiFi services in particular.

There are a number of sectoral WIMAX trials ongoing in Trinity College, NUIM and Letterkenny IT. Mobile WIMAX is still immature, not widely available and relatively expensive to implement. However industry indicators point to this technology maturing and becoming pervasive in the medium term. It will allow Mobile Broadband wireless access, fixed broadband wireless access, provide high speed backhaul. Recent advances in propagation technologies and mobile chipsets, combined with the reducing size of CPE (will be built into notebooks and laptops) support the impending widespread adoption of the technology. It is expected that it will be used in conjunction other wireless technologies in order to provide a ubiquitous wireless access solution to the end user.

#### Remote /Off Campus Access

A significant number of Higher Education Institutes have, or are in the process of implementing, remote access to campus services to both staff and students through a combination of technologies and applications including:

- Web based access via web based application interfaces including aggregated personalised service access through Higher Education Institute portals.
- Thin Client Access using Terminal Services, Citrix and SSL VPN access technologies.
- A limited number of predominantly legacy RAS solutions and no longer considered strategic

Off Campus access to these applications or gateways is typically provided by students or staff utilising either "personal" internet access including home broadband, commercial WiFi hotspots and

commercial mobile broadband access via 2.5G or 3G offerings via personal or business mobile devices including phones, PDA's and laptops.

### 5.3 Authentication - Eduroam

HEAnet has established and runs Eduroam Ireland, an active participant in a European wide initiative to allow users visiting other institutions to authenticate with the local Institution's using a single set of credentials in order to access the Internet, access their home institutes resources and in some cases the resources of the institutes through which the roaming user is accessing the network. HEAnet also provides the infrastructure into which Higher Education Institutes can connect to participate in Eduroam authentication. Currently five (5) Higher Education Institutes are active participants, four (4) are in the process of commissioning local infrastructure to become active participants and a further four (4) have indicated intention to join Eduroam but may not yet have all of the necessary elements in place.

### 5.4 User Broadband Penetration and Usage

National surveys indicate that there are 1.21 million active Internet subscribers with an estimated 31% of Irish households accessing the internet via broadband and an estimated 127,500 (+44% on previous quarter) mobile broadband subscriptions at the end of December 2007<sup>1</sup>. There are three operators providing Mobile broadband access in Ireland. They provide broadband access to subscribers with HSDPA upload and 3G/GPRS technologies for download. In general they provide HSDPA where available and this will fall back to 3G and GPRS seamlessly where the higher throughputs are either not available or oversubscribed with the coverage areas.

### 5.5 Licensing

WIMAX typically operates at 2.3, 2.5, 3.5, 5.8 and 26GHz. While Comreg will be making 5.8GHz available unlicensed (license exempt), it is expected to place restrictions on equipment, and interference restrictions may militate against any long range coverage unless low power-out base-stations are deployed outside the campus. The higher range 5.8GHz is not suitable for mobile solutions due to limitations imposed by poor signal penetration in buildings and reduced coverage in built up areas.

Indications are that the 3.5GHz channels currently available for licensing are primarily intended for Commercial use and that current unassigned channels F, G, H, I and J, would probably be dealt with in a similar manner.

Comreg has recently indicated that the frequency range 2300MHz – 2400MHz may be made available for Wireless Access **Platforms** for Electronic Communications Services under the European Commission Wireless Access Policy for Electronic Communications Services (WAPECS) initiative<sup>2</sup>. This proposes a range of electronic communications networks and electronic communications services may be offered on a technology and service neutral basis, provided that certain technical requirements are met, i.e., to avoid interference, to ensure the effective and efficient use of the spectrum and the authorisation conditions do not distort competition.

This may offer HEAnet and the Higher Education sector an opportunity to negotiate suitable spectrum (c. 2.3GHz) for developing a broadband wireless access solution for the sector.

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<sup>1</sup> Source Comreg Quarterly Report for the first quarter 2008 (18 March 2008)

<sup>2</sup> Comreg Proposed Strategy for Managing the Radio Spectrum: 2008 - 2010.

## 6 Key Requirements and Key Issues

### 6.1 Requirements

The following have been identified as key requirements for the successful delivery of HEAnet's Broadband Wireless Strategy for its delivery of a Wireless Infrastructure to the Higher Education sector:

- It will be provided for students, staff and nominated other users e.g. visiting staff, students, contractors, researchers.
- Access will provide connectivity via the Internet to Education and Research Networks and individual Institute provided services
- Access coverage will include Campus, near-Campus and National coverage.
- Mobile Broadband Access should include the whole island of Ireland.
- HEAnet clients will be active members of the Eduroam project and that this will be leveraged as a primary candidate for federated authentication

Other requirements include:

- Access will be provided at appropriate levels of throughput performance and with quality of service required to meet end user needs
- It should be easy to use from an end user perspective, requiring minimum levels of support or setup from Higher Education Institute IT support services
- It must be flexible and capable of offering new services and increased service and performance levels over time in line with national and international trends.
- It must be easy to manage, operate and administer from an Institute and or HEAnet perspective.
- It must conform to current usage policies, including carriage of education and research only data etc.
- It must leverage existing Higher Education investments and initiatives.
- It must also leverage existing state and commercial investments and initiatives – where these investments and initiatives can deliver on all of the Higher Education Institute requirements.
- It must adhere to relevant regulatory and competition authority guidelines and directives.
- It must provide value for money

### 6.2 Key Issues

HEAnet recognise that there a number of key issues to be addressed in order to execute a successful strategy plan in respect of mobile broadband Wireless access.

- Immediate need to provide full National Access in a timely manner and at affordable cost
- Need to ensure maximum participation and cooperation across the Higher Education sector including maximising uptake by end users
- Need to implement a standards based authentication framework in order to secure and facilitate access to services.
- Need to address the rapidly changing technology landscape in the delivery of Wireless access to end user community
- Need to secure funding and resources to implement Wireless Access Infrastructure
- Need to address potential licensing issues relating to spectrum and equipment deployment
- Need to demonstrate good value for money

In order to deliver on HEAnet's mission and address the above issues, HEAnet needs to:

- Deliver in the short term a solution which is easy to deploy and provides an acceptable and affordable level of mobile access to the end community
- Ensure Adoption of Eduroam throughout the Higher Education sector

- Continue highest level of communication and co-operation with Higher Education Institutes
- Ensure high levels of visibility for the strategy and implementations
- Develop and implement governance and review framework to monitor and review progress and recommend future courses of action
- Develop and secure a viable funding model
- Engage with Comreg and Commercial licensees in respect of acquiring Appropriate Higher Education licenses or developing agreements with current licensees.

## 7 Strategy

In addressing its Wireless strategy HEAnet will combine short term wins to meet immediate needs combined with medium to long term adoption of upcoming technologies. This roadmap entails the provision of adequate mobile wireless access at acceptable costs both to end users and to the Higher Education Sector, while taking cognisance of the changing landscape of mobile broadband technologies.

HEAnet and the Higher Education Institutes will adopt a phased approach to the delivery of wireless broadband and mobile wireless broadband access to its Clients. This entails the adoption of a multi-stranded multi-phased approach in delivering this access.

### Phase 1

- Delivery of a national mobile broadband access services by developing a service in conjunction with a commercial MNO.
- Continue to rollout Eduroam to all client sites
- Implement existing middleware strategy to support mobility
- Support current leading edge wireless technology trials and establishment of further pilot project
- Apply for licensed spectrum from Comreg
- Develop an implement suitable Governance and Review Framework for monitoring and reviewing strategy implementation and recommending courses of action to address changing environment.
- Do not implement a WIFI peering or transit service with commercial WIFI operators.

### Phase 2

- Delivery of on-campus and near-campus and national mobile broadband wireless access.

### 7.1 Phase 1

This phase (2008 – 2011) needs to commence without delay. It comprises a number of projects which will enable HEAnet to achieve a quick win for delivery of national mobile broadband access and allow HEAnet prepare for any future deployment of new high throughput technologies which will be available in the coming three years.

#### 7.1.1 National Coverage Mobile Access

It is recognised by HEAnet and the Higher Education Institutes that the only true “mobile” broadband offering currently available in the country is provided by commercial Mobile Network Operators (MNOs). There are three operators providing Mobile broadband access in Ireland. They provide broadband access to subscribers with HSDPA upload and 3G technologies for download.

HEAnet will run a public tender competition to facilitate the provision of national mobile wireless broadband access. HEAnet will leverage the large user customer base to implement a HEAnet Branded Offering for its customer base in conjunction with successful candidate operator.

The success of this approach will depend on:

- Maximum participation of Higher Education Institutes and a realistic level of adoption by end users over the lifetime of the contract - three years. (see table 7.1.1)
- Successful marketing of solution to the end user community
- Visible competitive advantage of the offering
- Active Participation of the Commercial sector and commercial viability of any offering which will be attractive to all parties.
- Engagement by each Higher Education Institute in conjunction for provision front of office support in conjunction with any support agreement entered into with the successful candidate.

Year	% Uptake	No. of Users
Year 1	10%	15,000
Year 2	20%	30,000
Year 3	30%	45,000

Table 7.1.1 Suggested Target Adoption Rates for the Service over 3 Years

**Actions required:**

- Prepare a specification and run a public tender competition
- Analyse and select appropriate offering
- Negotiate with selected candidate to finalise offering
- Develop and implement a marketing campaign
- Develop a support model
- Launch product /service offering

The competition to select the operator of choice will be based on criteria to include:

- Cost of solution
- Current Network coverage and availability of MNO
- Suitability of network performance
- Suitability of network capacity
- Willingness and ability of MNO to increase performance and availability in high student density areas
- Negotiate charges for Northern Ireland<sup>3</sup>
- Agreement on Branding

**Benefits**

This implementation will offer a number of immediately realisable benefits as follows:

- Can be implemented in a short timeframe
- Will provide national mobile broadband coverage
- Will provide coverage with MNO offering a high quality service and value for money
- Will provide leverage with the selected MNO to increase performance and availability in High Student density areas

**Disadvantages**

- Broadband access is limited by the technology, potential coverage issues and high density of subscribers in many areas.
- Cost of implementation and operation is relatively high

**7.1.2 Continue Rollout of Eduroam**

HEAnet will continue to facilitate the rollout of Eduroam to the Higher Education sector. Uptake is increasing and it is expected that all major Higher Education institutes will participate in the near future.

HEAnet provides a central National RADIUS proxy server<sup>4</sup> to which participating Institutes can connect via a locally installed RADIUS server. This model is congruent with our European NREN colleagues whereby these proxy servers relay authentication requests to and from their local

<sup>3</sup> O2 and Vodafone currently charge for Data roaming in Northern Ireland. "3" have no roaming charges between UK and ROI for customers using the 3 network. 3Pay customers can avail of 3 Like Home from 3 Italy and 3 UK and 3 Austria. <http://www.three.ie/international/faq.htm>.

<sup>4</sup> See <http://www.eduroam.ie/>

member institutions' Radius servers. These national proxy servers, in turn, relay requests via the European top-level Radius servers.

HEAnet will strive for maximum uptake of Eduroam across the sector.

#### Benefits

- It will provide a standardised roaming authentication vehicle in the Higher Education Sector
- It will facilitate federated authentication which will enable researchers and visiting scholars (even students where applicable) to gain automatic access to participating networks using their own home organisation credentials.
- It will reduce administration resource requirements needed to support guests on campus
- It will extend access to staff/students visiting other participating organisations

### 7.1.3 Implement Existing Middleware Strategy to Support Mobility

Currently there are no formal Higher Education provided federated services between Institutes. However there is an increased uptake of Eduroam across the sector. While Eduroam will provide a common Authentication mechanism, there is still a gap in respect of managing access to Campus resources across the sector

HEAnet and the Higher Education Institutes will implement a unified approach to Identity management which will complement and facilitate access to resources across the sector. This federated identity management solution which will:

- Improve the end user experience by enabling ease of access across Institute services on a policy basis
- Improve security for Institutes by providing a trusted, structured access and authentication framework for cross Institute users and affiliates.
- Reduce administrative burden for Institutes in creating or propagating other Institute user's identity on their networks or services.
- Provide an extensible federation framework allowing Institute and affiliate users to gain access to other Institute and affiliated organisation services

### 7.1.4 Wireless Technology Trials

WIMAX technology potentially offers the sector complementary on-campus and extended campus coverage as well as significant performance and capacity improvements over current mobile wireless (MNO) offerings. Mobile WIMAX is still immature, not widely available and relatively expensive to implement and thus should not be considered an economic production capable wireless network technology for the sector in the short term. However industry indicators point to this technology maturing and becoming pervasive in the medium term. It will affectively be the main competitor to the mobile industries 4G offering.

There are a number of sectoral WIMAX trials and implementations ongoing including

- Trinity College
- NUIM
- Letterkenny IT<sup>5</sup>

HEAnet will participate in campus based WIMAX trials/pilots as follows:

- Provide support for the TCD and NUIM ongoing trials
- Select one more candidate institution to operate as a Greenfield trial site

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<sup>5</sup> Letterkenny IT currently delivers wireless beyond its campuses over wireless to a small number of users. It also provides expertise to a number of service providers to expedite the provision of wireless broadband (WIMAX) access to small businesses and community projects, in areas where larger commercial providers do not provide fixed or wireless broadband access.

- Provide Financial assistance to pilot/trial deployments
- Provide technical assistance to pilot/trial deployments by employing a Wireless expert who will:
  - Liaise with participant on behalf of HEAnet and the Higher Education Sector
  - Provide Wireless Expertise to the trial/pilot sites and to the Higher Education sector
  - Report on trial/pilot outcomes and findings to HEAnet and the Higher Education Sector
  - Remain current with technology changes in the wireless technology area
  - Provide recommendations on course of action to HEAnet and the Higher Education Sector based on these findings
- Assist participating Institutes with potential licensing issues by engaging with Comreg

It is understood that any trials or pilots may be co-implemented by the Individual Higher Education Institutes, commercial backers or industry deploying new technologies and HEAnet in the interests of research or commercial

### **Benefits**

There are no downsides to this approach. The investment is relatively small. However, for this low investment it will allow HEAnet and the sector to keep options open in respect of the WIMAX technology being the technology of choice against the mobile industry's 4G future offering:

- HEAnet would be a stakeholder in the particular trials,
- Results of trials/pilots would be available to all HEAnet customers
- It would provide a consolidated approach to potential Higher Education Sector implementations of future deployments.
- It will allow the sector to make informed decisions in respect of technologies to deploy (WIMAX or 4G or hybrid, combining elements of both).
- It can be used to increase visibility of HEAnet as an innovative and world-class networking resource
- The investment is relatively small.
- It would not preclude future deployments from being implemented on either a commercial or fully private basis.

### **7.1.5 Licensing and the Communications Regulator**

HEAnet will engage with Comreg to discuss potential licensing requirement in respect of wireless deployments which may not use license exempt frequencies. This engagement will address:

- Allocation of a specific set of channels operating on the same frequency through out the country, where these frequency/channel assignments are outside the current FWALA assignments.
- A potential licensing arrangement with Comreg in the lower "licensed" bands, preferably in the 2.3GHz, 2.5GHz or 3.5 GHz range on a geographic basis
- Potential allocation of one or more of the unassigned channels in the 2.3 GHz range

HEAnet will also consider developing agreements with commercial providers in possession of appropriate licensing, whereby this license may be utilized for both commercial and private networking in the campus and greater campus area.

### **7.1.6 Governance and Review**

HEAnet will establish appropriate governance and review mechanism of the Wireless strategy to:

- Measure the outcomes and success of the short term strategy
- Review, assess, recommend and deliver appropriate new wireless technology, deployment and commercial models as appropriate to achieve medium to long term goals

This will entail a creating a review and monitoring framework/process which will facilitate

- Measuring levels of adoption of solutions
- Identifying areas of difficulty in implementation
- Quantifying success of strategy solution implementations
- Assessing suitability of new technologies based on:
  - Trials/pilots
  - Changing customer requirements
  - General adoption rates
- Provide recommendations on any changes to strategy

## 7.2 Phase 2

This phase (2009+) will be dependent on a number of factors:

- Outcomes of pilot/trials
- Successful implementation of phase 1
- Technology uptake in broadband wireless
- Major changes to customer requirements
- Potential licensing agreements with Comreg

### 7.2.1 On-Campus and Extended Campus Deployment

HEAnet will facilitate the construction of WIMAX campus and near-campus infrastructure on Higher Education Institute campuses which will integrate with other wireless infrastructure technologies to maximise broadband wireless and mobile broadband wireless access for end users. These will be co-ordinated between Higher Education Institutes in adjacent geographical areas to extend the reach and create a larger coverage area.

Use of license exempt frequencies would probably entail using frequencies in the 5.8GHz range, and would not be interference protected. It is envisaged that any WIMAX deployment will require some form of licensing. This may be achieved by:

- Acquiring appropriate licensing
- Creating a partner arrangement with a current commercial license owner.

Base on the results of Pilot and trial programs, it is envisaged that

- The infrastructure would be built by HEAnet or the Higher Education Institute and licensed through a commercial arrangement with a commercial provider with required licensing (unless appropriate licensing can be secured by HEAnet)

Or

- Outsourcing the implementation and management of the network to a third party licensed provider, with a commercial arrangement for use of premises to offset costs and access charges

This infrastructure would be extended to include extended off campus coverage and will combine WIMAX, WLAN and cellular technology in the delivery of the service.

It is envisioned that participating HEAnet clients must be active members of Eduroam and that this Eduroam will be utilised as the primary candidate for federated authentication.

#### **Benefits**

- Will provide high data rate throughput
- Would be owned/part-owned by HEAnet/Higher Education Institute
- Could be implemented and managed by the individual Higher Education Institutes (with HEAnet) or in conjunction with the partner Service Provider
- Could utilise Eduroam as the authentication mechanism of choice

- Could leverage the expertise of potential commercial partners in designing the network deployment
- Licensing and regulatory issues would be addressed by third party

Mobile WIMAX will allow direct connection to an IP network. 4G (LTE) as used by the mobile sector. It will also connect directly to an IP network and not through the mobile network as is the case with 3G and HSPA technologies. It may be the case that in 2011 both technologies will be integrated. It may also be the case that total coverage for Campus, Near Campus and National may comprise a combination of WIMAX, mobile WIMAX and LTE as provide by commercial operators or that WIMAX be not be realisable commercially as a mobile access technology.

## Appendix A – Glossary of Terms

3G	Third Generation Wireless
3GPP	3rd Generation Partnership Project
CDMA	Code-Division Multiple Access
CPE	Customer Premise Equipment (e.g. antenna/router/modem)
FDM	Frequency Division Multiplexing
FMC	Fixed-Mobile Convergence
FMS	Fixed-Mobile Substitution
FTE	Full Time Employee
FUSC	Full Usage Of Sub-Channels
FWA	Fixed Wireless Access
FWALA	Fixed Wireless Access Local Area
FWPMA	Fixed Wireless Point To Multipoint Access
GPRS	General Packet Radio Service
GSM	Global System For Mobile Communications
HEI	Higher Education Institutions
HSDPA	High-Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High-Speed Uplink Packet Access
LTE	Long Term Evolution (Utran)
Mbs	Megabit per Second
MNO	Mobile Network Operator
MVNE	Mobile Virtual Network Enabler
MVNO	Mobile Virtual Network Operator
OFDM	Orthogonal Frequency Division Multiplexing
OPex	Operating Expenses
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
W-CDMA	Wideband Code-Division Multiple Access
WiFi	Wireless Fidelity
WIMAX	Worldwide Interoperability For Microwave Access
WISP	Wireless Internet Service Provider
WLAN	Wireless Local area Network
WMAN	Wireless Metropolitan Area Network