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## Closing the digital divide in Papua New Guinea: A proposal for a national telecommunications model

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### Abstract

We propose a model that could close the digital divide in PNG by integrating mobile with complementary technologies such as fixed network, fibre-optic cables, WiMAX and VSAT among others. Central to this model are the domestic fiber-optic cables installed on PNG Power line poles, those of the PNG LNG partner companies, as well as the PPC-1 undersea fiber-optic cable connecting Guam and Sydney with a branch into Madang providing high speed international connectivity. While the former pair can serve national high speed needs, by facilitating interconnection of complementary technologies, the latter will provide connectivity to the international cloud. The model requires policy and regulatory support for transparent and equitable access to infrastructure enabling high speed connectivity within and between PNG and the rest of the world.

**Key words:** Digital divide, mobile communication network, network elements, GSM network, HLR, VLR, GPRS, 3G, WiMAX, CDMA, AMPS, fiber-optic cable network (Refer glossary at the end of the article for other key words.)

### Introduction

Various geographical challenges to telecommunications in PNG have long since been acknowledged (Sinclair, 1994). They are caused by mountainous and swampy terrains, as well as a thinly scattered population, and necessitate a combination of technologies to provide telecommunication services that can reach the wider population across PNG. We propose a national telecommunications network model to provide high speed national voice, data and video connectivity between mobile and complementary technologies to attain broadband ubiquity, bridging the digital divide across PNG and providing high speed connectivity to the world. In this paper, the expression 'digital divide' is taken to mean the gap in the availability and accessibility of digital services between urban and rural areas of PNG.

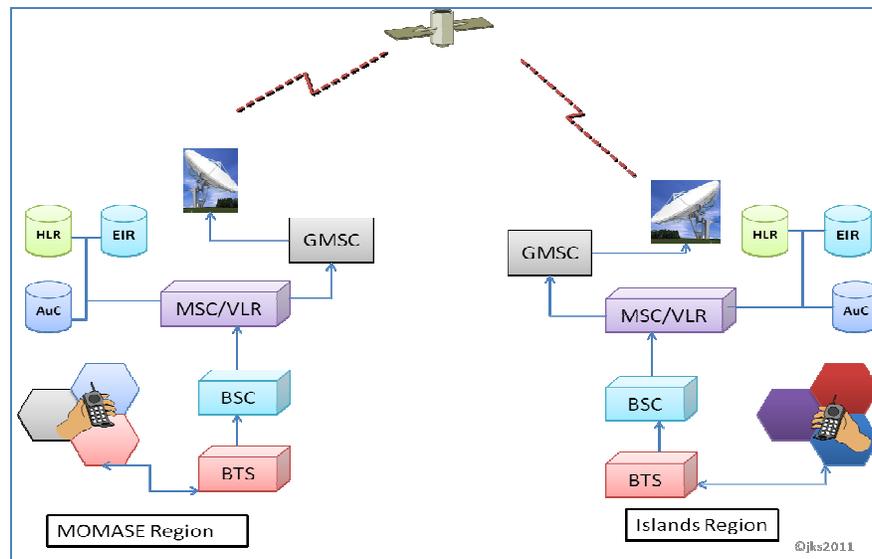
The model is designed to promote the objectives of the PNG development strategy (MTDS, 2005-2010, p. 32), in particular its reference to the present limited access to information technologies stating that 'To date, access to information technology has been severely limited by several factors, including lack of the necessary physical and technical infrastructure, high illiteracy rates, and poor education levels'. It is expected that mobile connectivity made available across PNG could be harnessed by the education, health and other services to improve national socio-economic conditions.

As presented here, the model is generic and the technical discussions on the complementary technologies are purposely brief. However we do attempt to discuss compatibility and interoperability requirements between the relevant technologies.

### Cellular mobile communications in PNG

Cellular mobile communications were introduced in PNG in May 2002 with Telikom PNG (TPNG) providing a service based on the American standard, Advanced Mobile Phone Service (AMPS) which is an analogue circuit switched cellular technology designed for voice traffic and using the Frequency Division Multiple Access (FDMA) method. It is classified as a first generation (1G) cellular technology. This service was restricted to Port Moresby and Lae, was decommissioned in 2004 and replaced by the Global System Mobile (GSM) digital and global technology using circuit switching which delivers higher capacity, encryption and roaming. GSM is a second generation (2G) digital and global technology using circuit switching which delivers higher capacity, encryption and roaming. GSM supports digital voice communications over switched networks and is widely available in PNG. Roaming allows use of the mobile phones by travelers to other countries with which PNG has billing agreements.

To serve wider areas of PNG, separate cellular networks could connect regions of PNG using a satellite link as backbone (Figure 1). The issues with satellite transmission are latency and bandwidth limitations which severely limit 3G voice, video and data communications. Improvements can be achieved by using fiber-optic cable in the backbone where possible.

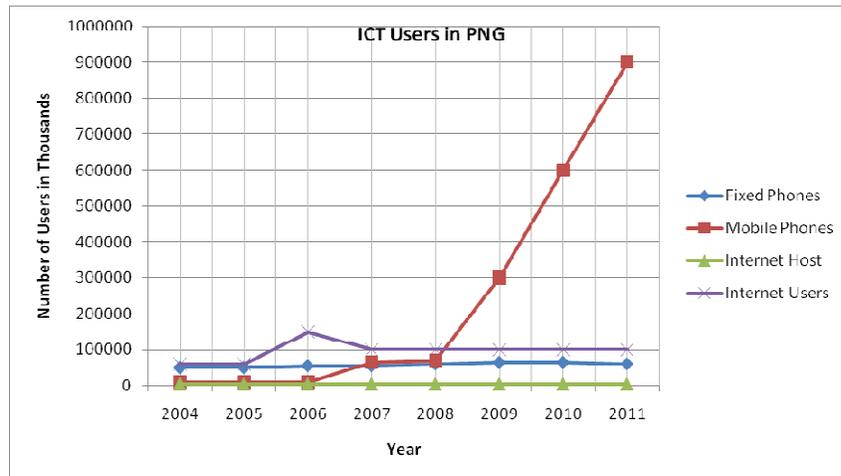


**Figure 1: GSM support for digital voice communications over switched networks.**

Individual handsets must be located within a hexagonal cell where they connect to a Base Transceiver Station (BTS) which receives and retransmits the voice signal. Multiple BTSs connect to a Base Station Controller (BSC) which controls handoffs as a user might move from one cell to the next; these in turn connect to a Mobile Switching Centre (MSC) where call switching within the network can occur or where connection can be made to another network such as shown here. The EIR, HLR, VLR and AuC, described later, provide user identification and billing to allow roaming between mobile networks, both locally and internationally.

While GSM also was initially confined to urban areas, the entry in July 2007 of a new provider, Digicel PNG Ltd saw the extension of mobile phones services further across PNG and a greatly increased uptake of this technology (Figure 2). TPNG also provides a Code Division Multiple Access (CDMA) based mobile service in parts of PNG where fixed land line services already exist. CDMA is a mobile phone access technology in which each user has access to the whole available spectrum, but is able to use a unique code to encrypt each call separately.

The growth in usage of ICTs across PNG remained flat for many years prior to the competition provided by the introduction of a new mobile operator Digicel in July 2007. Since then the mobile phone sector has seen unprecedented growth across PNG.



**Figure 2: The growth in usage of ICTs across PNG.**

(Source: <http://www.nationmaster.com/country/pp-papua-new-guinea/med-media>, retrieved 18<sup>th</sup> July 2011)

However, many rural areas of PNG still lack landline telephones, faxes, television services, computers and Internet connections. Although most of these digital services are available and have been enjoyed by those living in urban areas, the rural areas have largely been neglected (Watson, 2011). We propose a model with the potential to address this situation.

Mobile telecommunication access methods presently available in PNG include CDMA, Time-Division Multiple Access (TDMA) which allots each mobile user access to regularly repeating time slots to carry the communication signal, GSM, and General Packet Radio Service (GPRS) which follows 2G but is packet switched. It acts as a data overlay on GSM networks and is referred to as a 2.5G technology. GPRS allows data communication such as Internet connection using mobile phone technology. 3G mobile which carries voice, video and data allowing videoconferencing and Internet connectivity, is also available as a recent addition and has been introduced in some urban areas, and may gradually extend more widely across PNG. As well, mobile Wireless Interoperability for Microwave Access (WiMAX) is becoming available. WiMAX is the name of an industry forum which supervises the implementation of the IEEE 802.16 standard for wireless metropolitan area networks (WMAN). This standard provides a high speed data access technology (4G) representing a general upgrade of all features of mobile technology.

While in-campus wireless local area networks (WLANs) are served for wireless access by WiFi, many rural and remote areas are served only through Very Small Aperture Terminals (VSAT) which are parabolic antennas used for accessing communication satellites for commercial use in long distance communication. WiFi is an industry forum for implementing the IEEE 802.11 point-to-multipoint wireless LAN technology with a range of approximately 100M.

### **Model design**

The proposed model is designed to integrate mobile with complementary technologies such as the fixed network, WiMAX, CDMA and VSAT among others by using the two available domestic fibre-optic cables as a backbone supporting high speed transmission of telecommunication traffic. The aggregate out-bound and in-bound traffic on this domestic network could allow international connectivity via the PPC-1 undersea fiber-optic cable linking Sydney to Guam and with a branch at Madang (Anderson & Kim, 2011).

The available domestic fibre-optic cable networks include one owned by PNG Liquefied Natural Gas (LNG) with partners, and another terminating at PNG Telekom Madang Exchange and hosted by PNG Power line poles. Using these, the aim is to connect the coastal and highlands regions of PNG to produce a high speed domestic network with a further gateway connection to the PPC-1 cable.

Interoperability between different technologies to ensure seamless broadband access is a basic assumption of our model. This will require conditioning of Points of Interconnection (POI) where two or more networks physically or electronically connect to facilitate origination, transit or completion of traffic. They provide signalling and protocol compatibility within and between the network elements forming the fabric of the model. Such conditioning will also provide information to determine billing and charging arrangements between networks.

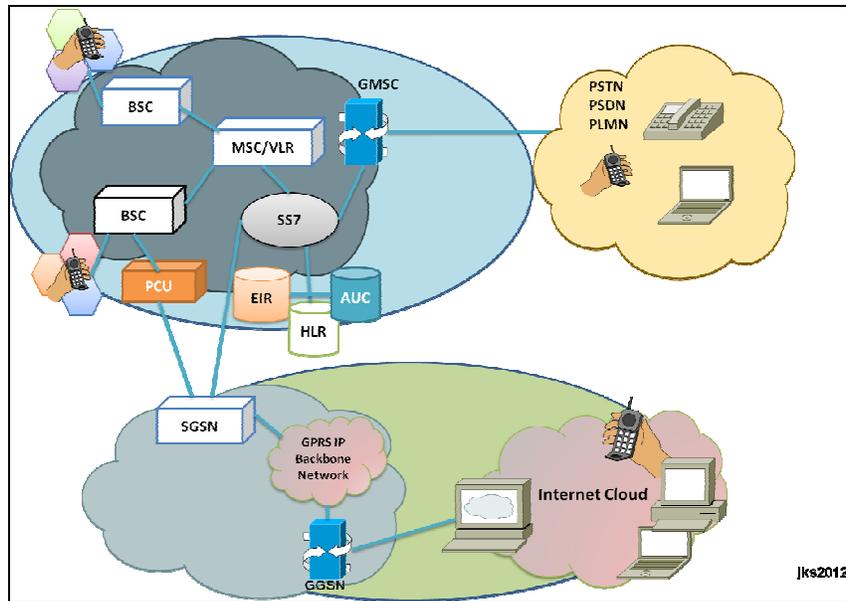
### **Mobile technology in the model**

While the bulk of current mobile usage is still voice-centred, the need for data transmission as well was recognized with the introduction of the previously mentioned GPRS as an overlay of GSM (2.5G), and later 3G technology in 2011. In 3G the basic architecture of GSM (Figure 1) networks was upgraded to support the transmission of voice, video and data over a communication system.

In PNG this migration commenced with the inclusion of the GPRS components in 2008 overlaid on the GSM network in order to enable the transmission of data up to 9.6 Kbps and services such as facsimile, videotext, and teletex. 3G is offered in certain urban areas of PNG and further expansion can be expected.

The provision of roaming both within PNG and internationally by GSM requires registration, authentication, call routing, and location updating. Together with the Mobile Switching Center (MSC), these functions are performed by the Home Location Register (HLR), Visitor Location Register (VLR), Authentication Center (AuC) and Equipment Identity Register (EIR) with the aid of the Signalling System 7 (SS7) protocol for call synchronization (Figure 3). SS7 is the signaling system or ITU protocol standard used by telephone companies to set up telephone calls in the Public Switched Telephone Network (PSTN) and also to control the network.

With GSM (Figure 3), used by both Digicel and B-Mobile, the user can originate or receive a call (voice or data) while roaming in areas of GSM signal coverage. Calls can be made to/from a PSTN, Public Switched Data Network (PSDN), or another Public Land Mobile Network (PLMN) when the calling/called parties are authenticated and authorized by the GSM network. To the core elements (Figure 3, blue region) are added (green region) the GPRS network which allows the transmission of data packets and making this a 2.5 G network.



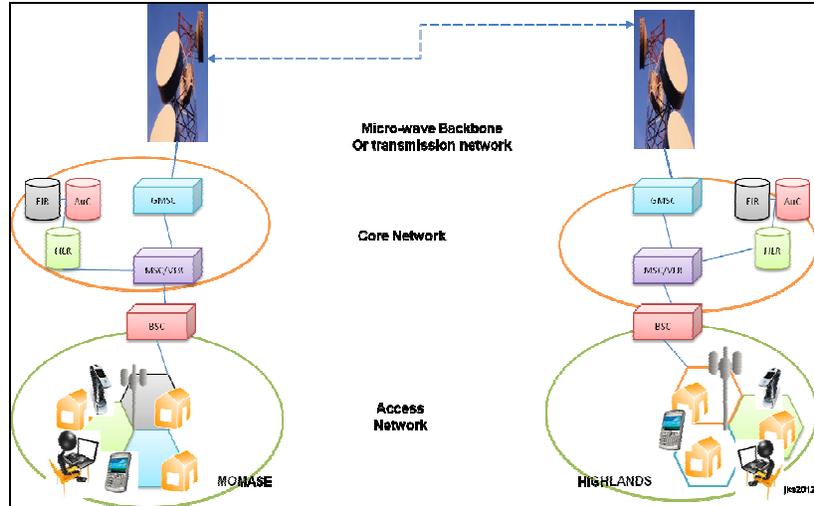
**Figure 3: Elements of a GSM network.**

Connection of the mobile network to the PSTN is made by the Gateway Mobile Switching Centre (GMSC) which can also receive voice calls from other MSCs. Connection to a data network is made via a Serving GPRS Support Node (SGSN) which sends connection requests to the Gateway GPRS Support Node (GGSN). The GGSN authenticates the user, initiates the billing system and then makes the connection to the data network (Internet cloud).

Communication between a handheld device and the Base Transceiver Station (BTS) takes place via the air interface which in PNG uses the 900 MHz, 1900 MHz and 2100 MHz bands depending on whether it uses GSM, GPRS or 3G.

A hypothetical GSM network (Figure 4) also could connect two distant geographical areas via microwave backbone. Initially in PNG, a centralized switch in Port Moresby was deployed where all mobile calls were transmitted for switching. Now decentralized switches are available in some regions (LAE switch for the Momase region and the Mt Hagen switch for the highlands) where traffic is switched, routed or terminated locally.

The BTS and the BSC feed and receive signals to and from the Network. The BSC manages the radio frequency resources for BTSs such as radio channel setup, frequency hopping, and handovers. This is also called a handoff and is the switching of an on-going call to a different channel or call as becomes necessary for a mobile user.



**Figure 4: A hypothetical GSM network for the model**

The HLR contains all the administrative information of each subscriber registered in the network along with the current location of the mobile device. The location is given in the form of the signalling addresses of the VLR associated with mobile station. In the case of B-mobile or Digicel, it could be just one HLR with each network, although implementation could be distributed in other centers such Lae, Mt. Hagen, or Kokopo or it could be centralized within the main MSC, say Port Moresby.

The VLR contains administrative information from the HLR for call control and provision of the subscribed services in the geographical areas and is located within the MSC. Thus the area controlled by the MSC corresponds to that controlled by the VLR which simplifies the signalling required. For authentication and security the EIR contains the database of all valid mobile equipment on the network where each mobile device is uniquely identified. If a customer in Madang reports a stolen phone, the International Mobile Equipment Identity (IMEI), a unique number that identifies each mobile phone handset, can be marked as invalid, rendering the unit inoperable. The AuC is a protected database that stores a copy of the secret key stored in each Subscriber Identification Module (SIM) card used for authentication and encryption over the radio channel.

As a backbone for these mobile technologies, we now consider two emerging domestic fiber-optic cable initiatives namely the PNG LNG fiber-optic and the PNG Power hosted fiber-optic projects which together should prove invaluable to the ICT sector and the overall PNG economy.

### LNG fibre-optic cable in the model

The LNG fibre-optic network follows the gas pipeline providing branching units with access points for interconnection to mobile operators, WiMAX, CDMA and fixed line service providers along the route.

At the customer access level, fiber-optic cable can offer speeds greater than 100 Mbps. The LNG Cable project (with partners: PNG govt (41.67%), Esso Highlands (33.33%), oil Search (16.67%) and Southern Highlands provincial government (8.33%)) is envisaged to aggregate the assets owned by Telikom and hosted by PNG Power to form a high speed backbone network to enhance competition and accessibility. This high speed backbone network will greatly improve transmission capacity and make connectivity ubiquitous bringing Internet access to a much wider customer base throughout PNG (Business, 2011).

By following the LNG pipeline (Figure 5, Source: Independent Public Business Corporation presentation (2011)), those areas along the route of the pipe line can be adequately served including interconnection arrangements with the PNG Power hosted network, the mobile networks, fixed network, CDMA and VSATs among others. For this model to provide equal and non-discriminatory access, relevant regulatory and policy support would be necessary.

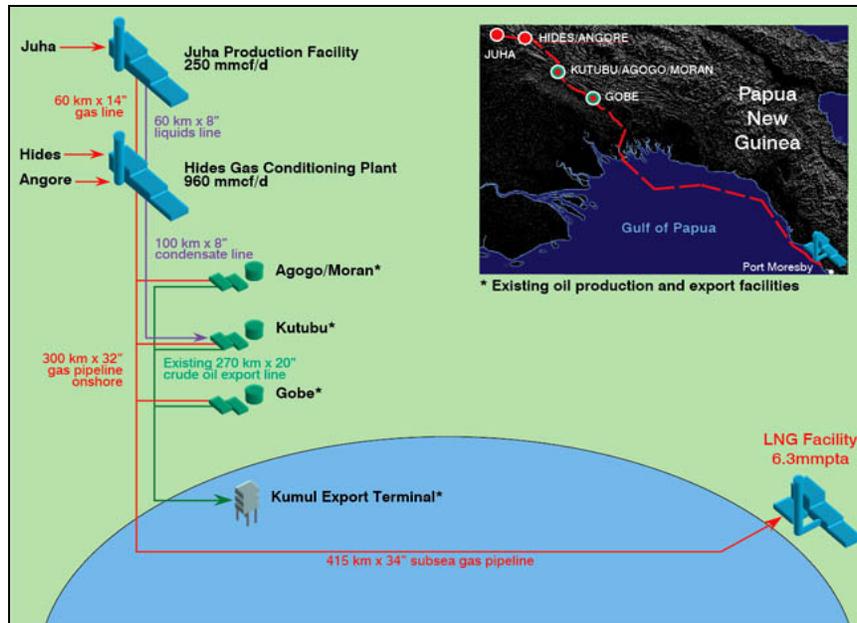


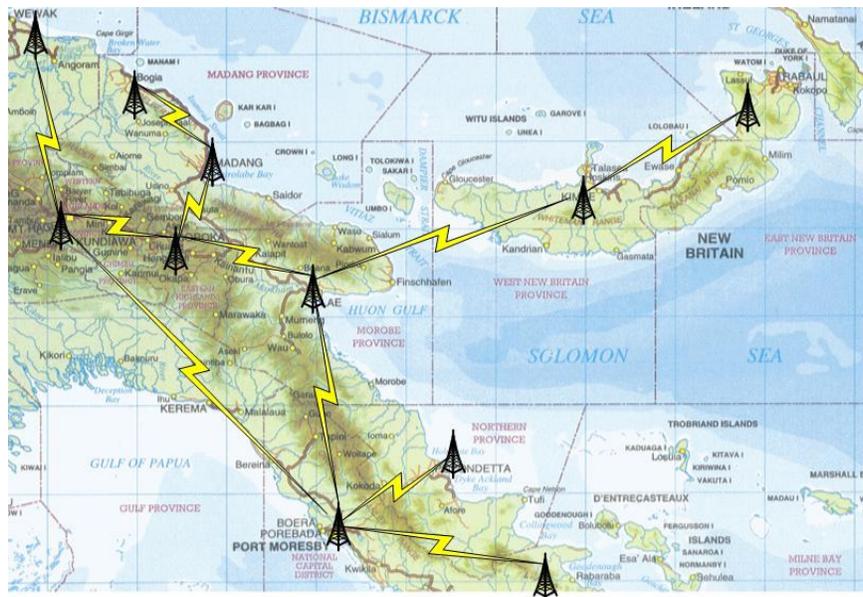
Figure 5: The LNG pipeline

### PNG Power hosted fiber-optic cable in the model

The LNG pipeline will transport gas from the Hides, Angore, and Juha gas fields for the Asian market via a 716 km gas pipeline (Figure 5, shown in red) to a two-train LNG facility at Napanapa near Port Moresby. Kutubu and Agogo processing plants (shown in green) will produce condensate for the Kumul Export Terminal. The gas produced as a by-product from this plant will be returned to the LNG pipeline. The relevant fiber-optic cable will follow this gas pipeline with branching units to access points for interconnection to mobile operators, WIMAX, CDMA and fixed line service providers along the route.

The TPNG internal domestic telecommunications trunk network is a backbone network (Figure 6, Anderson & Kim, 2011) which largely relies on microwave resources through a chain of repeaters on mountain peaks, providing point-to-point links between distant locations. Line-of-sight microwave (5-7 GHz) services require chains of repeater stations located every 50 km on the mountain peaks.

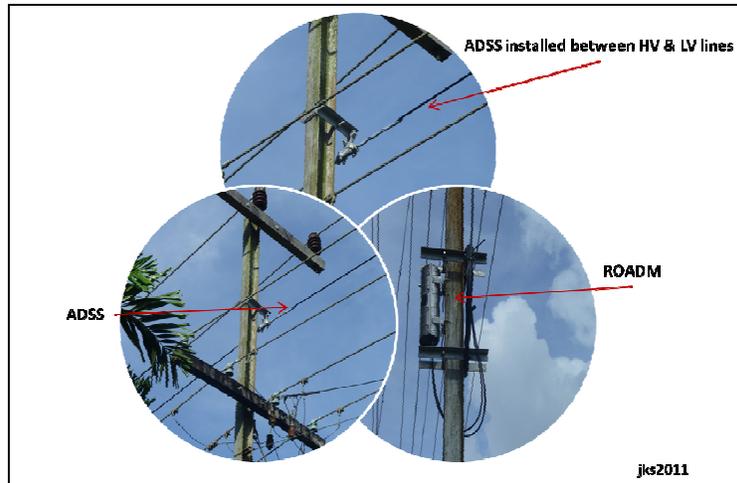
However there are bandwidth and other limitations for use of this network for high speed traffic including issues such as vandalism, theft and land owner compensation claims.



**Figure 6 TPNG internal domestic telecommunications trunk network.**

As an alternative we note that PNG Power has an established electricity generation and transmission network which also extends to rural areas of PNG under its rural electrification program.

This existing power grid infrastructure is now being used to host, construct, test and commission Optical Ground Wire (OPGW), All Dielectric Self-supporting Aerial Cable (ADSS) and Approach cables (Figure 7). Approach Cable is normally installed between the final splice box, forming the termination of the ADSS in the power line and Fibre Distribution Panel installed within the terminal building. This fibre-optic cable network would link Madang and Lae through Walium, Gusap, Yonki, Mutzing and Erap gradually rolling out to the highlands. In the highlands, there is an opportunity to interconnect this fibre-optic cable to the PNG LNG fibre-optic cable further increasing coverage. The purpose of this network is to provide high speed back bone communications within and between places in PNG.



**Figure 7 All dielectric Self-supporting Aerial Cable (ADSS).**  
Source: jks2011. Images were taken along Modilon Rd Madang within a few km of the Telikom Exchange termination point

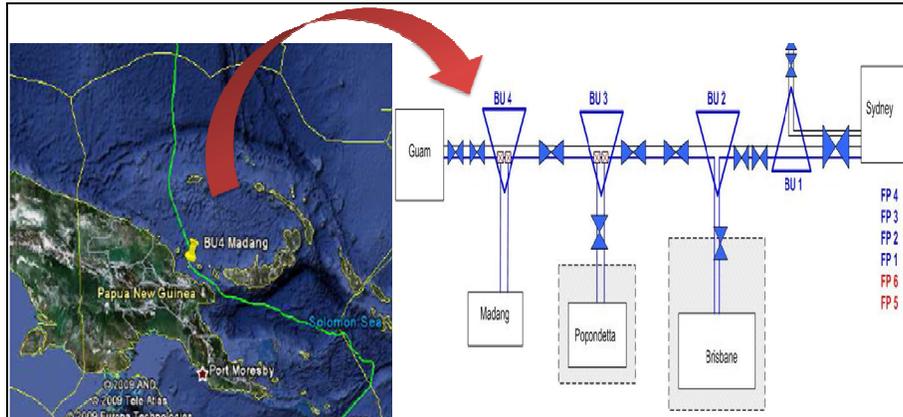
ADSS has the capacity to offer 10 Gbps of data transmission enabling faster backbone connectivity. The option to provide high speed core to the edge is also possible providing opportunity for users to have access to high speed Internet. The ADSS cables can be seen as a single wire running between the High Voltage and Low Voltage lines along the Madang town roads (Figure 7). To enable Remote add/drop of wavelength (as bandwidth), Optical add/drop multiplexers (ROADM) are installed every 2 kilometers on the power poles as seen on the lower right photo. While providing high speed backbone for Service providers, the option to offer high speed to users along those areas is possible.

The potential offerings from the PNG Power hosted fiber-optic cable are considerable including high speed backbone connectivity for mobile and fixed line operators, WiMAX service providers, Internet Service providers among others. Then a potential speed of up to 10 Gbps high speed internet and multimedia services can be enjoyed by end-users given appropriate core to access conditions.

Equitable access should be promoted through transparent and accountable policy and regulatory instruments in the interest of public good.

### The Sydney-Guam cable in the model

The undersea fiber-optic submarine cable (Anderson & Kim, 2011) which runs from Guam to Sydney (Figure 8) and has a landing station in Madang provides international connectivity for PNG.

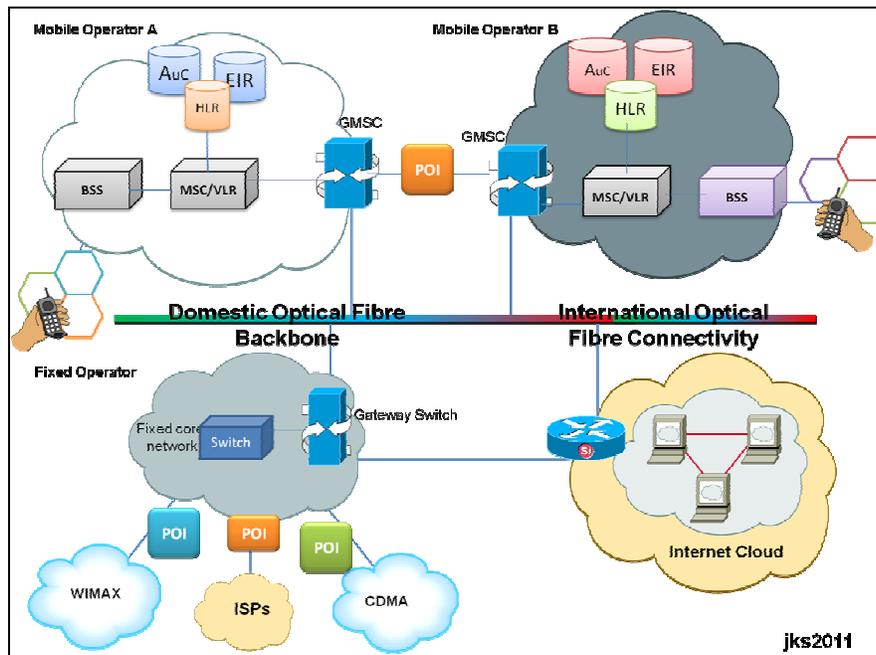


**Figure 8: Branching unit to Madang from PPC-1** (Adapted from: [www.pipenetworks.com/docs/media/ASX%2009\\_03\\_24%20PPC-1%20Presentation.pdf](http://www.pipenetworks.com/docs/media/ASX%2009_03_24%20PPC-1%20Presentation.pdf). Available 7-Aug-12.)

The branching unit of the PPC-1 at Madang (BU4) offers a capacity of 10 Gbps providing international connectivity for in-bound and out-bound traffic. The feed from the aggregate traffic from the mobile, fixed, WiMAX, and other technologies from within PNG consolidate to form seamless end-to-end high speed traffic flow.

The role of this cable in the model would be to connect to the in-nation backbone (LNG and PNG Power hosted cables) to provide international connectivity.

### Completing the proposed model



**Figure 9: Proposed telecommunications model for PNG.**

Our proposed model (Figure 9) is designed to provide seamless connectivity across PNG through equitable access to infrastructure, in particular the domestic fiber-optic cable owned by LNG and the PNG Power hosted cable. It envisions a robust backbone network comprising of fiber-optic cables accessible to all operators on equitable terms and conditions. It has the potential to provide seamless end-to-end communication across PNG and the rest of the world. As the cellular technology follows migration paths to provide 3G voice, video and data, this model should be capable of providing the required robust backbone network. It includes the under-sea cable owned by TPNG for international connectivity.

#### Advantages of the model

The proposed telecommunication model for PNG envisions a robust backbone network comprising of fiber-optic cable accessible to all operators on equitable terms and conditions. The model links the two mobile operators to each other (top) and to the fixed data and voice networks (eventually connecting to the Internet), all through the proposed integrated fiber-optic backbone.

The implementation could be undertaken through a Public-Private Partnership (PPP) arrangement because it can result in sharing of experiences, cost and benefits in the national interest. Seamless high speed Internet access for the

wider population such as schools, hospitals and government, together with general voice-centric services could then be enjoyed across PNG.

The model interconnects the fixed telephone network together with the GSM network and CDMA with WIMAX utilizing the fiber-optic cable as the backbone. The upgrade to 3G networks for mobile networks can be supported through upgrades in the respective network elements to enable e-services to be enjoyed across PNG.

Overall the Information and Communication Technology (ICT) sector can benefit according to Metcalf's law which states that the value of the network is proportional to the square of the number of connected users ( $n^2$ ). Hence by integrating other complementary technologies to the mobile using the fiber-optic cable as the backbone, the aggregate user base will increase, thereby achieving economies of scale and increasing the value of the respective networks.

### **Standardization of technologies**

PNG is primarily an end-user of technologies rather than a manufacturer. As a consequence all information technology products are imported from many different manufacturers in other countries. These products are of varying standards and experience has shown that different products are not always interoperable which means that integration between networks deploying different technology becomes a challenge. This is a standardization issue that has to be carefully observed and addressed to ensure that compatibility and interoperability and migration to newer/proven technologies are progressed smoothly.

If this is neglected, denial of service or even poor quality of service will be experienced by the end-users in this nation as has been experienced. Such a situation can result in an increased digital divide which can negatively impact on the socio-economic development aspirations of the nation. Moreover, services can be costly because economies of scale are not realized given that technologies are not compatible enough to attain critical mass.

To ensure interoperability and compatibility within and between networks, every effort must be made to strengthen national capacity on standards. This can be achieved through collaboration between regulatory and standards bodies, the industry and academia. Manufacturers of the products should be part of this collaboration process because PNG is where they sell their products.

### **Conclusion**

We have proposed a model to integrate a number of existing or developing national wireless networking infrastructures to provide a high speed wide area national network. The essence of the model is to support existing mobile and fixed communications networks with an integrated nation-spanning system of

fiber-optic cables which follow the national highway and have international connectivity. The model will support the aspirations of the government to provide nationwide information technology connectivity upon which socio-economic activities can progress. Moreover it will support the rollout of broadband services and extend the reach of individual networks through integration of mobile with complementary technologies.

ICT service providers can increase their bottom line through economies of scale realized through increasing number of registered users. Other sectors such as the health, education and even government can harness the ubiquity of broadband for their own special purposes.

The challenges that need to be overcome are many, including policy and regulatory support for the industry. Such policy and regulatory foresight should aim to improve competition to encourage more investment in the sector and the introduction of more technologies across PNG. Moreover, standardization gaps between technologies should be addressed through collaboration with all stakeholders.

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### Glossary

1G	First Generation Cellular Network	LNG	Liquefied Natural Gas
2G	Second Generation Cellular Network	MSC	Mobile Switching Centre
3G	Third Generation Cellular Network	OPGW	Optical Ground Wire
4G	Fourth Generation Cellular Network	PPC	PIPE Pacific Cable
ADSS	All Dielectric Self-Supporting Aerial Cable	PPP	Public Private Partnership
AMPS	Advanced Mobile Phone Service	PSDN	Public Switched Data Network
AuC	Authentication Centre	PSTN	Public Switched Telephone Network
BSC	Base Station Controller	PLMN	Public Land Mobile Network
BU	Branching Unit	POI	Point of Interconnection
EIR	Equipment Identity Register	ROADM	Remote Optical Add Drop Multiplexer
FDMA	Frequency Division Multiple Access	SIM	Subscriber Identification Module
GGSN	Gateway GPRS Support Node	SGSN	Server GPRS Support Node
GMSC	Gateway Mobile Switching Centre	SS7	Signalling System 7
GPRS	General Packet Radio Service	TDMA	Time Division Multiple Access
GSM	Global System for Mobile Communications	TPNG	Telekom PNG Ltd
HLR	Home Location Register	VLR	Visitor Location Register
ICT	Information Communication Technology	VSAT	Very Small Aperture Terminal
IEEE	Institute of Electronic & Electrical Engineers	WiMAX	Wireless Interoperability for Microwave Access
		WLAN	Wireless Local Area Network
		WMAN	Wireless Metropolitan Area Network