Satellite Communication for PNG Universities and Research Institutes: A New Design

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Abstract

An academic and research satellite-based digital wide area network (WAN) has been established for universities and other national research institutions in Papua New Guinea (PNG). The network which is providing cost-efficient electronic digital communication and high speed Internet access is described for both client and server side installations. The network has the potential to unify the efforts of member institutions to educate the citizens of the nation, to gain the synergy available from collaboration, and to avoid wasteful duplication of scarce resources. Workings of government and academia, as well as general education can be enhanced and PNG can move forward swiftly to take advantage of the Information Communication Technology (ICT) revolution sweeping the world.

Key words: satellite communication, PNGARNet, academic or educational research networks, technology

Introduction

For some years now in Papua New Guinea (PNG) there have been efforts made to overcome the challenges to national systems of communication provided by the natural geographic barriers of mountain ranges, un-crossable river deltas and seas which separate the PNG islands. There has also been the need to provide institutions of higher learning with low-cost Internet access. Since the defunding and so commercialisation of the Internet, these types of challenges have been attenuated in many countries by the construction of national data communication networks linking consortia of multiple institutions. Such networks will be briefly listed before turning attention to PNGARNet which is presently being constructed under the sponsorship of the vice-chancellors of the universities of PNG. The technology used will be illustrated with a view to pointing out multiple design advantages.

Motivation for academic and research networks

The Internet is essentially a set of meshed[1] data communication backbones[2] commonly known as ‘fat pipes’ which carry data through packet switched

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[1] A mesh network, as its name implies, provides redundant paths for data transfer. Should any part of the network fail, alternative paths for data transfer are expected to be available.

networks[3]. Service providers acting as global, national (NSPs) or local Internet service providers (ISPs) form a hierarchy of bandwidth[4] wholesalers and retailers each passing on costs which are eventually met by the end-user accessing the World Wide Web (WWW) or other Internet services such as the instant global communication tool known as email. The Internet had its origins in the United States of America as a cold war strategy to provide a redundant mesh network which could never be completely disabled by enemy intention, thereby contributing to national security. Thus, one of the early backbones known as the Advanced Research Project Agency Network (ARPANET) was funded in the early 1970's by the Defence Advanced Research Project Agency (DARPA). By the early 1980's the National Science Foundation (NSF) had funded a new backbone named NSFNET to further develop the system of backbones which became known as the Internet.

The Internet became so well used that in 1995 NSF was able to defund NSFNET and its full commercialisation was implemented. Commercial firms were now able to invest in further backbone development. This meant that bandwidth had to be paid for and so began the era of the academic or educational research networks for organisations such as educational, academic, and scientific institutions in order to assist these non-profit organisations with cost-effective and vitally important communications and Internet access. These networks are built and owned by typically nation-wide consortia providing economical access and data[5] sharing between member institutions. The networks are also able to take advantage of the economy of scale available from bulk purchase of Internet bandwidth from the various levels of service providers.

Academic and research networks

A national academic and research network is designed to provide for low cost digital data communication between member institutions of higher education and research as well as low cost high bandwidth (speed) access to the Internet. The technology to develop these networks is now readily available using off-

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[2] As indicated by the alternative title of 'fat pipe' a backbone is a high capacity (high speed or large throughput or 'bandwidth') trunk (multiple multiplexed signal channels) circuits.

[3] Data in whatever form is carried in electronic packets (TCP/IP packets) much as a postal letter is carried within an envelope carrying source and destination. Each packet is self contained and makes its own best path (determined by routers) through the multipath network independently of other packets which might be part of the same communication. Again the analogy of the posted letter is applicable.

[4] Bandwidth (*sensu stricto*) of a communications channel is the difference between the maximum and minimum frequencies (cycles/sec or Hertz) which are permitted by regulating authorities or which the impedance of the channel will permit. Throughput (commonly known as bandwidth – *sensu lato*) is the number of bits (data carrying binary digits) per second (bps) that the channel can carry after conversion to a digital or digital over analog conversion. This definition of bandwidth is also referred to as the 'speed' of a connection. Broadband refers to a channel which can carry multiple channels typically using frequency multiplexing. However, the term more frequently refers to any channel carrying more data than a dial-up modem.

[5] Data here is taken to mean any form of packetised digital communication, be it computer generated or voice or video communication.

the-shelf equipment[6], in particular using satellite technology and earth station equipment to access that technology.
Examples of such networks include:

- AARNet (Australian Academic and Research Network)
- USPNet (University of South Pacific internal network)
- Many European examples (eg JANet in UK)
- ERNet – a 2001 proposal for PNG.

University of South Pacific internal network (USPNet)

The University of the South Pacific (USP) runs an internal network (USPNet) that links Suva to 14 centres spread across 12 South Pacific Island nations (Figure 1). USPNet utilises a variety of stable satellite technologies to service multiple campuses. The network services 15 000 on-campus students and 17 000 other students throughout the South Pacific region. This successful implementation suggests that the technology is now mature[7] and worthy of consideration for PNG where provincial cities are similarly separated by natural barriers.

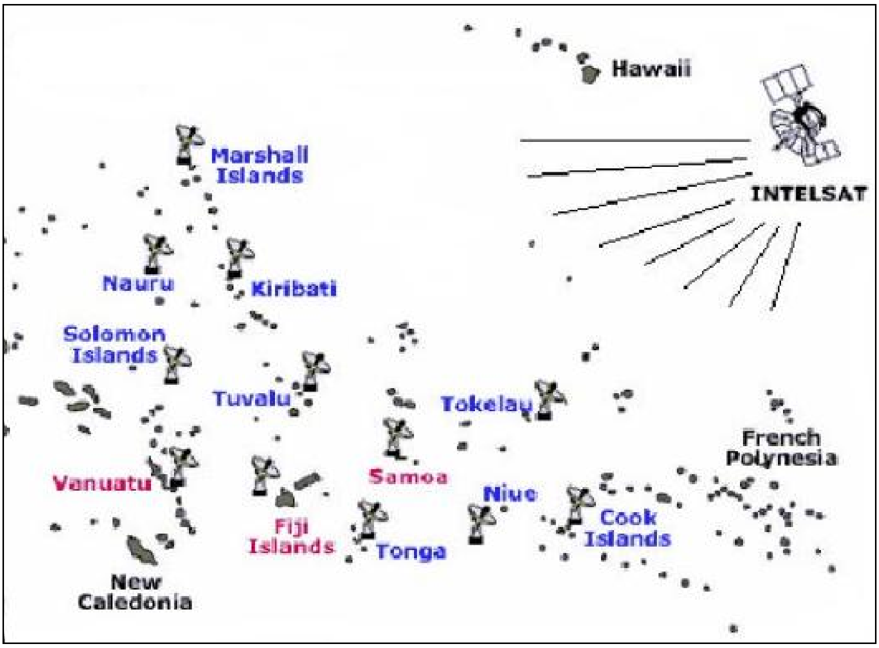

Figure 1 Using the INTELSAT communication satellite, USPNet links USP to its campuses and other centres across 12 South Pacific Island nations using a variety of

[6] Equipment to be used at each client location will be supplied by iDirect Technologies (see http://www.idirect.net) which provides IP communications technology in collaboration with satellite channel providers. AsiaSat4 will be the communications satellite used.
[7] In 1964, only 7 years after the successful launching of Sputnik 1 in 1957, the International Telecommunications Satellite (INTELSAT) Consortium was formed to establish a system of global communication satellites.

satellites and stable technologies to service 15,000 on campus students and 17,000 other students (L. Fitina, 2006, personal communication). The suitability of this technology for overcoming natural physical barriers is evident.

Education and Research Network (ERNet): a Proposal for PNG

A proposal for a PNG Education and Research Network (ERNet) was developed by the Network Feasibility Study Team, within the Office of Higher Education and published in April 2001[8]. The design was based on land line and microwave backbone transmission to link all PNG educational and research institutions on a cooperative basis as well as providing an Internet gateway. This proposal asked the right questions and came up with the best solutions available at the time.

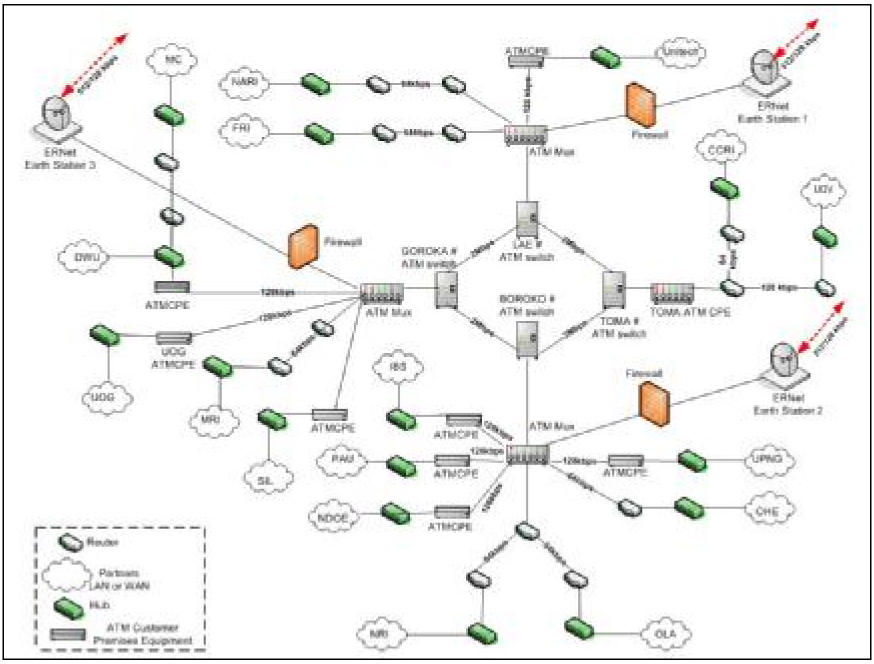

Figure 2 A land line design proposed for ERNet in 2001 to link PNG education and research institutions and to provide bulk purchase of bandwidth for Internet access. Whilst the design was quite visionary, it was expensive and required a level of funding that was not available at the time. Presently available off-the-shelf technologies involving satellite rather that land line communication overcome many of the problems offered by this design.

Compared with the presently implemented PNGARNet design discussed below, there would have been significant difficulties involved in the implementation of ERNet. As well as relatively high costs (greater by a factor of 10 than the design to be discussed in this paper), considerations included the

[8] The Network Feasibility Study Team (2001), The *Education and Research Network Feasibility Study Report*, OHE PNG: Government Printing Office.

need for multiple maintenance sites, the challenges provided by natural geographical barriers, the real possibility of deliberate, accidental or natural damage to cables, the legal problems involved in negotiations with landowners, and general security issues involved in care of remote sites.

PNG Academic and Research Network (PNGARNet)

The design now being implemented for a PNG Academic and Research Network (PNGARNet) is based on satellite technology (Figure 3) to provide the backbone giving all member institutions their own chosen access rates to system wide resources and the Internet via a teleport and hub located at the Network Operations Centre (NOC) in Hong Kong. The use of a communication satellite overcomes the difficulties involved in a land line network listed above.

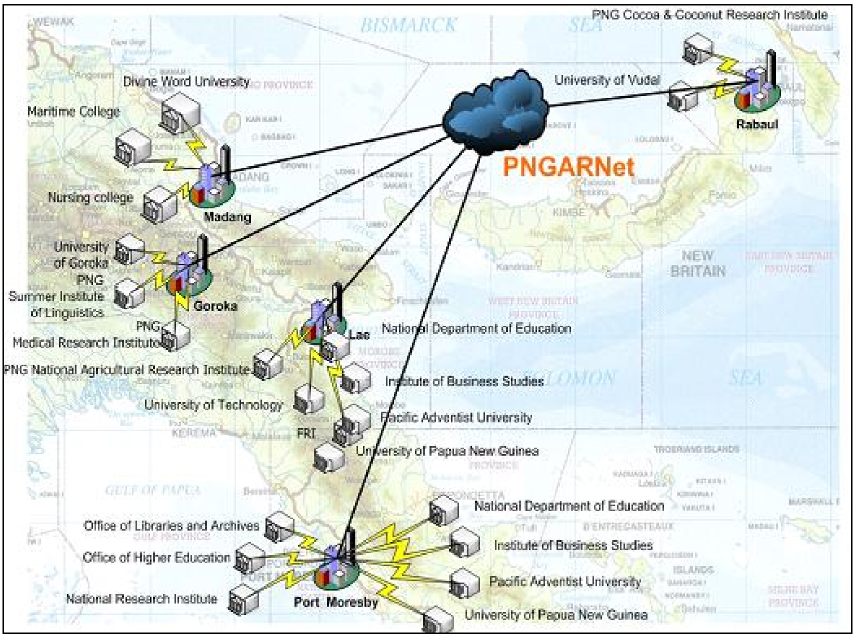

Figure 3 Beginnings of the PNGARNet data communication network linking PNG education and research institutions. The AsiaSat 4 communications satellite provides the data communication channels between institutions as well as Internet access through a Network Operations Centre in Hong Kong.

Readily available technology in the form of Very Small Aperture Terminals (VSATs) and associated switches and routers are now available for earth-based stations to communicate with other stations via an established commercial satellite. As well as being an order of magnitude less expensive than a land based design as noted above, this design based on wireless point-to-point communication will avoid the problems related to laying cables or setting up microwave towers listed above for the proposed ERNet.

Satellite technology

Satellite communications technology became affordable for commercial applications in the 1980s (with further improvements in the last 5/6 years) with the development of Very Small Aperture Terminals (VSAT)[9] which take advantage of microwave signals[10] with the associated high frequency and so small wavelength allowing use of smaller terminals[11] and highly focused beams. Understanding this technology is an important prerequisite for appreciating the advantages of the current design. We discuss orbits, transponders, transmission frequencies and available bandwidth.

Geostationary orbits

The speed and height of satellites in geostationary orbits allow them to remain synchronised above a specific location on the earth at all times[12]. Maintaining fixed positions relative to earth positions enables earth transmitting and receiving stations to direct their terminals to fixed positions of azimuth (horizontal) and elevation (above the horizontal) in the sky.

Transponders

Transponders are repeaters carried by communication satellites which are powered from solar cells on flat panels. Each transponder consists of a receiver tuned to an uplink frequency band, a frequency shifter to change frequency to downlink frequency band and a transmitter to broadcast on the downlink band, and a power amplifier for the downlink signal.

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[9] Dodd (2005) p. 466. High frequencies used enabled the development small VSAT terminals which were affordable for commercial organizations. VSAT antennas are used widely to link branch locations back to a central location for wide area networks. They are also used for bank ATM services requiring credit authorisation, EFTPOS terminals, and commercial retail outlet chains requiring daily inventory reports. Now ARNets are able to exploit this new technology.

[10] Microwave signals are forms of electromagnetic radiation that occupy the electromagnetic spectrum from approximately 1 to 300 GHz (30cm to 1mm in wavelength) although authors do vary on the exact range of this classification. This gives a total bandwidth of 300 GHz which is very large compared with the Radio Frequency (RF) bandwidth of only about 100 MHz, thereby greatly increasing their data-carrying capacity. First generated in the late 1930s with Klystrons and Magnetrons, microwave properties were initially exploited in radar devices for detecting enemy aircraft and shipping in World War II. Superior technology used by the allies is believed to have greatly shortened the length of the war. Modern methods of microwave generation have made microwave technology more available, although microwave ovens still use magnetrons. Microwaves have high data-carrying capacity (related to the very high bandwidth mentioned above) and can be tightly focused for line-of-sight transmission.

[11] The size of the terminal or parabolic dish is directly proportional to the wavelength of the signal used. Use of microwave frequencies with correspondingly small wavelength enables the development of small terminals.

[12] The earth's gravitational attraction provides just sufficient centripetal force to keep the satellite in stable (geostationary) orbit when the satellite has sufficient speed to maintain a stable orbit 35 800 km above the surface of the earth and in the plane of the equator.

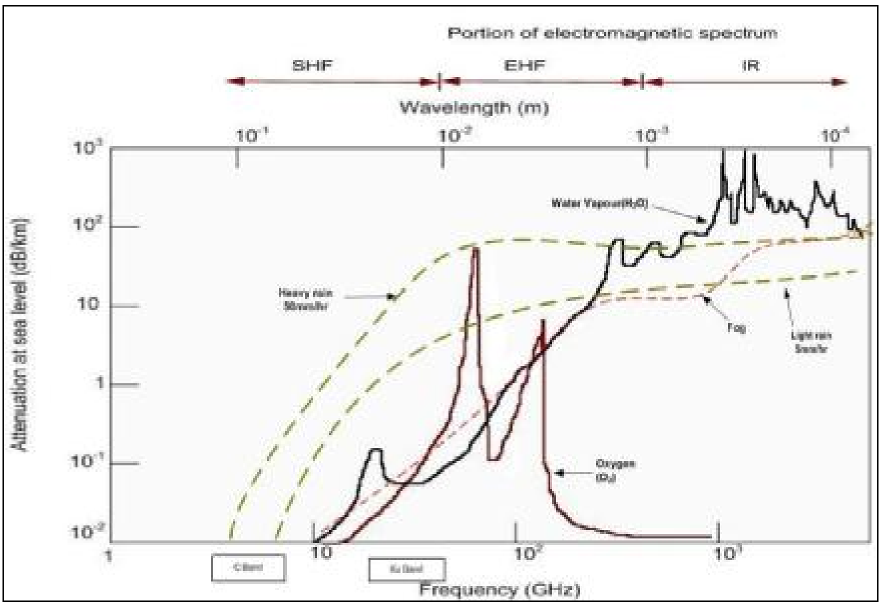
Transmissions

The frequencies used in satellite communications are in the microwave region of the electromagnetic spectrum. Being of such high frequencies, line-of-site transmission is required, but this is readily available in the earth-satellite space. The particular advantage of such high frequency, made available since 1993 with improved digital technologies, is related to the fact that the higher the frequency of a carrier signal, the more digital data it can carry. AsiaSat4, the PNGARNet data-carrying satellite uses what is known as the C-Band (designated as such with associated frequencies by international convention). Another common satellite technology uses Ku band. Table 1[13] shows the frequencies used in each of these bands.

Table 1 shows two commonly used microwave frequency bands used by communication satellites. See also Figure 4.

Frequency Band	Uplink	Downlink
C Band	3.4 to 4.2 GHz	5.925 to 6.425 GHz
Ku Band	11.7 to 12.2 GHz	14.0 to 14.5 GHz

These microwave frequencies follow straight lines, cast sharp shadows and fall within spectral windows where there is relatively low absorption by atmospheric moisture (fog and rain) (Figure 4).



[13] Sheldon 2001, p. 1100. Uplink and down link frequency bands differ to avoid signal interference. Bands are selected to exploit spectral windows where absorption by atmospheric gases is at a minimum relative to neighbouring regions of the spectrum.

Figure 4 shows the extent of atmospheric absorption (attenuation) of frequencies in the microwave region and above[14]. In general the higher the frequency the greater the level of absorption. SHF (superhigh frequency) and EHF (extremely high frequency) are within the microwave range of frequencies. Clearly infrared frequencies suffer too high an attenuation for long distance atmospheric communication. Infrared frequencies are used in guided transmission such as occurs in fiber-optic cables (Section 3.2)

Limitations of satellite technology

Free space loss[15] of the signal occurs by atmospheric absorption (eg. fog and rain) on both the uplink and downlink paths can be significant (Figure 4). This loss needs to be minimised by using high gain antennas and repeaters. As already noted, the C and Ku satellite frequency bands have been chosen to minimise this atmospheric attenuation.

There is also a problem with the time delay or latency involved in forward-and-return transmission as in telephony. This can be approximated in the following calculation for minimal time-delay[16] with straight up-and-down transmission:

$$\text{Time delay} = \text{S(distance)/V(speed of light)}$$
$$= 2*35.86*10^6/3*10^8$$
$$\sim 0.23 \text{ Sec}$$[17]

Time delays of about 0.5 sec are experienced in longer back and forth paths such as might occur in intercontinental transmissions. This can be a problem for time-critical applications such as voice communication involved in telephony. Such delays, noticeable (and irritating) in telephone communications, could also create problems for other time-critical data transmissions such as the updating and reconciling of databases.

It is also worth noting also that solar cells on flat panels are the only source of power on communication satellites.

Communication satellites have a life expectancy of about fifteen years, the length of time commercial operators have to recoup costs and profit on their investment. Thus the cost of satellite communication is also significant.

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[14] Adapted from figure provided in ‘Telecommunications Media’. Encyclopaedia Brittanica 2007, Chicago: Encyclopaedia Brittanica, 2009.

[15] See Valdar, 2006, p. 72. Free space loss, the signal attenuation which occurs as a signal passes through the atmosphere, is particularly acute when earth stations are located at high latitudes requiring a relatively longer passage through the atmosphere because of low angles of elevation of the earth station terminals. This loss is significant even though the atmosphere, being a thin envelope approximately 100 km thick, occurs over only a small portion of the path to the satellite

[16] Of course time delay will be increased in a realistic calculation because of the separation of ground station and hub on the surface of the earth such as occurs in intercontinental transmissions.

[17] This calculation uses a geostationary orbit of 35 860 km above the surface of the earth and the speed of light as 3 00 000 km/s

Fiber-optic alternatives

Fiberoptic cables became operational in the 1970s based on the principle of total internal reflection of transmitted infrared[18] signals in hair-thin glass fibercores embedded in a series of protective layers. Problems encountered in satellite communications, mentioned above, have been largely overcome by replacing unguided atmospheric transmission with undersea fiberoptic cables at least for intercontinental data communication.

With fiberoptic signal strength is maintained over much greater distances with very little attenuation, cable installations are more permanent, and data carrying capacity (throughput or bandwidth) is higher.

Undersea fiber-optic cables for intercontinental data transmission have been mapped[19] and the portion of that map relevant to PNGARNet is shown in Figure 5.

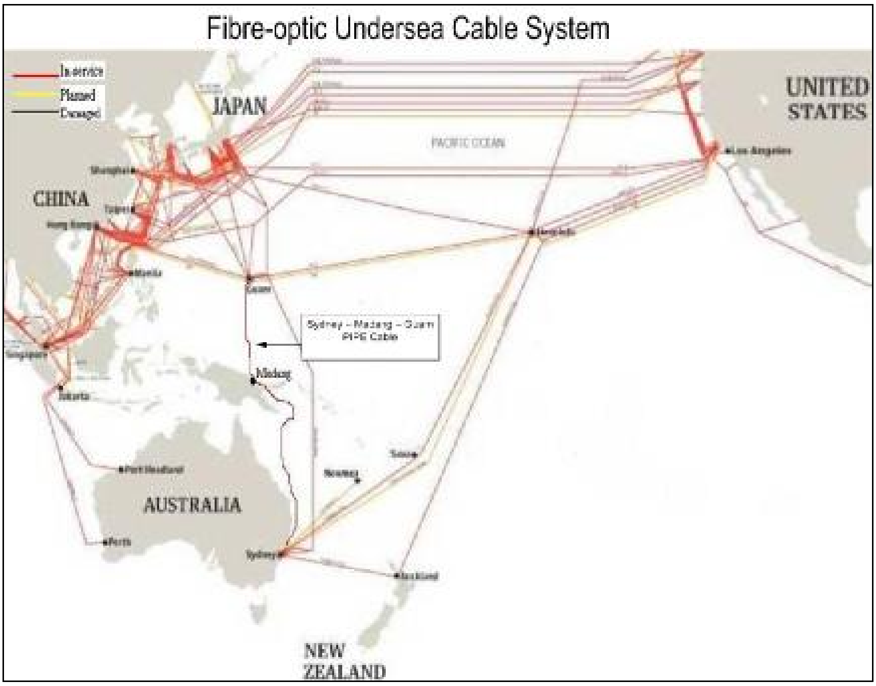

Figure 5 Portion of the published world map of undersea cables. Note the density of cables entering and leaving Hong Kong where the Network Operations Centre (NOC) for PNGARNet is located. This will enable ISPs to provide PNGARNet users high speed access to the Internet. Shown also is the Sydney-Guam PIPE cable which has an outlet to

[18] Infrared light data carrying pulses are conveniently generated by light emitting diodes. The actual wavelengths chosen are those that suffer least attenuation in the glass fiber used.

[19] See Worlds Fiber Optic Network http://migs.wordpress.com/2008/02/10/wow-worlds-fiber-optic-cable-network/

> Madang, PNG via a junction box about 80km off the coast from Madang. Fiber-optic access to the Internet, might therefore eventually replace the satellite connection to the Hong Kong NOC.

The density of cables at PNGARNets's Hong Kong Network Operations Centre (NOC) will enable ISPs there to provide PNGARNet users high speed access to the Internet. A recently installed cable from Sydney to Guam cable which has an outlet to Madang, PNG via a junction box located about 80km off the coast from Madang[20] . This cable initially terminates at the Madang telephone exchange (Figure 6). From there fiber-optic switches will provide fiber-optic links to major data users in Madang including Divine Word University (DWU) which will then have the capacity to become the new NOC for PNGARNet. The undersea cable might, therefore, eventually replace the satellite connection to the Hong Kong NOC.

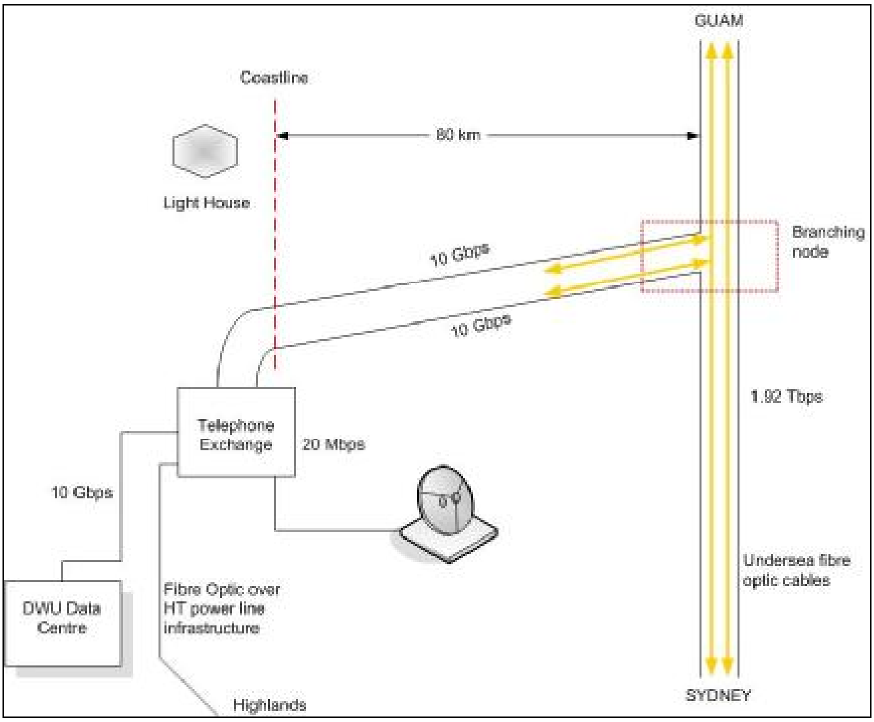

Figure 6 shows detail of the Sydney-Guam undersea fiber-optic connection (PIPE Cable), presently being installed, as it relates to the Madang region. Some fibers in the cable will provide a connection to a fiber-optic switching station at the Madang telephone exchange and from there to local subscribers. This connection has the potential to eventually replace the PNGARNet satellite communication network through the DWU Data Centre shown in the diagram. This would overcome the difficulties associated with satellite communication as well as providing higher bandwidth.

[20] This cable linking Sydney and Guam with a direct link into Madang is known as the PIPE cable. This will be the preferred form of carrying international data traffic from PNG as it provides superior voice and data transmission, with satellite communication remaining as a backup.

PNGARNet administration

PNGARNet is owned by a registered consortium consisting of the PNG University Vice-Chancellors and Directors of Research Institutes. The intended use is for non-profit organisations, both non-government and government. It is expected to eventually have a user base of an estimated 27 000 staff and students.

The basic operational agreement was that, initially at least for the first six months of operation, the DWU Information Technology Services Department would provide the hardware expertise and consultancy, a reference point for all enquiries, contacts and agreements, assistance with satellite installation and coordination, and negotiation of billing arrangements.

Member institutions

The potential partner categories include universities, research institutions, teachers colleges, nursing colleges, technical colleges, government and other non-government organisations. Because member institutions are required to provide their own internal equipment and software solutions, prevailing internal limitations of local area networks (LANS) may be a limiting factor in determining the rate of uptake by potential member institutions. At the time of writing (August, 2009) PNGARNet member institutions included the following.

Pacific Adventist University (PAU), 2 sites
PNG Institute of Medical Research (PNGIMR) 2 sites (Goroka and Yagaum (Madang))
PNG National Agricultural Research Institute (NARI) 6 sites (Lae, Aiyna, Tambul, Kilakila, Laloki, Kevevat)
PNG National Research Institute (NRI)
PNG University of Technology Unitech) 2 sites (Lae, Bulolo)
PNG Summer Institute of Linguistics (SIL)
University of Goroka (UOG)
University of Papua New Guinea (UPNG)
University of Vudal (UOV) 2 sites (Vudal, Popondetta)
Divine Word University (DWU) 5 sites (Wewak, POM, DBTI – Boroka, Vunapope – SM School of Nursing, Binatang – Madang)

Establishment costs

Each client site provides its own equipment which is most visibly a 3.0 or 3.7 M VSAT antenna depending on the size of the institution. The reflector and support assembly (Figure 7) shows the basic antenna design in cross section. The support structure contains adjustment for both azimuth (horizontal) and elevation direction settings for alignment with the geostationary communication satellite. The reflecting paraboloid surface directs parallel microwave rays to the second Cassegrain[21] reflector. From there the microwave signal enters the feedhorn waveguide. Under the reflector are located the Block Upconverter (BUC) and the Low Noise Block (LNB)[22]. A coaxial cable can then carry the lower frequency signal to the indoor units (IDU).

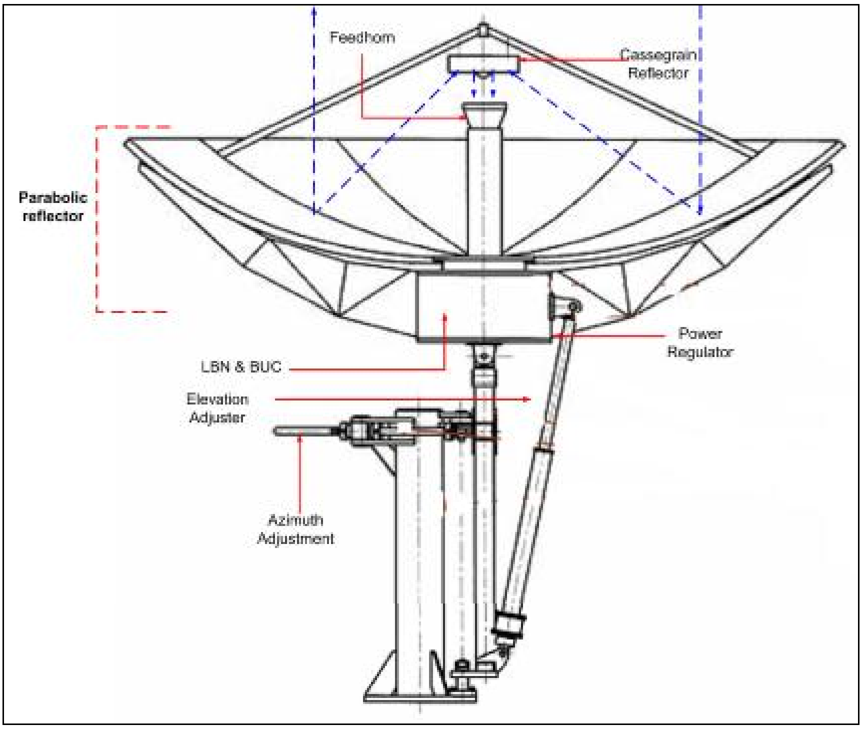

Figure 7 shows a 3.7 M VSAT antenna (adapted from vendor's manual) with its reflector and support structure assembly in cross section. The support structure contains adjustment for both azimuth (horizontal) and elevation direction settings. The reflecting paraboloid surface directs parallel microwave rays to the second cassegrain reflector. From there the microwave signal enters the feedhorn waveguide. Under the reflector is located the Block Upconverter (BUC) and the Low Noise Block (LNB) The LNB and BUC provide the conversions to and from lower frequencies which can be transmitted on coaxial cable (RG6) to the microwave frequencies of propagation. A coaxial cable can then carry the lower frequency signal to the indoor units (IDU).

[21] The Cassegrain reflector returns the signal back through the reflecting surface via the feedhorn. This enables the large BUC and LNB devices to be located under the reflector rather than out in front as required by a Ku band antenna.

[22] The BUC (outbound signal) and the LNB (inbound signal) are each involved in converting the signal to or from microwave frequency. Microwave frequencies can only be transmitted in expensive cylindrical or rectangular hollow metal tubes known as wave guides. Radiation loss would rapidly occur in less expensive coaxial cable and so frequency conversion occurs to enable transmission via coaxial cable to and from the indoor units.

Client-side equipment (Figure 8) for member institutions also includes a core switch which services the institution-owned LAN which is connected to satellite equipment via the router. The Virtual Private Network (VPN) gateway provides a private (encrypted) channel (sometimes called a tunnel) for the institution preventing its data being accessed by unauthorised users. The modem converts the data from the LAN into a form suitable for transmission through unguided media. This data travels over RG6 (Radio Guide) coaxial cable, before it is converted to microwave frequency suitable for transmission by the VSAT parabolic antenna by the Block Upconverter (BUC).

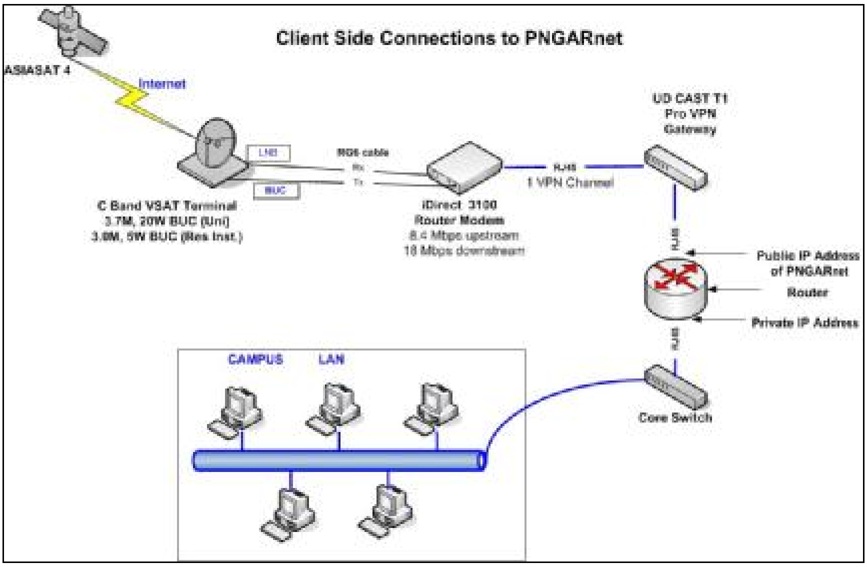

Figure 8 shows the equipment needed at each client (member institution) site for connection to PNGARNet. The core switch services the institution owned LAN which is connected to satellite equipment via the router which separates PNGARNet from the institution's LAN. The Virtual Private Network (VPN) Gateway provides a private channel (sometimes called tunnel) for the institution preventing its data being accessed by other users. The modem converts the data from the LAN into a form suitable for transmission through unguided media. This data travels over RG6 (Radio Guide) coaxial cable, before it is converted to microwave frequency suitable for transmission by the VSAT parabolic antenna by the Block Upconverter (BUC).

Other costs include the fee for the bandwidth and Contention Ratio of choice, site running costs, satellite connection fee and costs of installation and commissioning. Various connection options (Table 2) are available and are chosen by the client institution on the basis of cost and institutional needs.

Table 2 Bandwidth options available for member institutions as provided by the carrier provider, Oceanic Broadband

	Option 1	Option 2	Option 3	Option 4
Uplink	1 Mbps	1 Mbps	256 Kbps	128 Kbps
Downlink	5 Mbps	2 Mbps	512 Kbps	256 Kbps
Contention Ratio[23]	5:1	5:1	5:1	5:1

Centre establishment costs

Centre costs will be shared by participating partner institutions. The initial setting up of PNGARNet has already been completed with the registration of the company and early discussions with the central hub in Hong Kong and the bandwidth providers. Use of Open Source software is reducing costs. Hardware costs include the purchase of Mail server, Database server, server configuration, switch, VPN concentrator and installation costs.

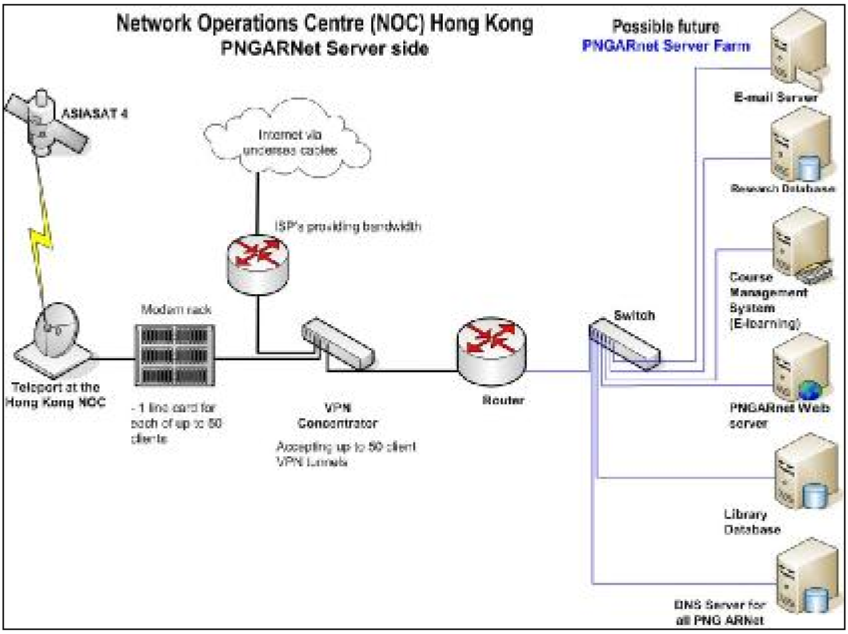

Figure 9 shows server-side equipment at the NOC in Hong Kong**.** Each client institution has its own VPN channel which is accepted by the VPN concentrator which can accept up to 50 channels. Each channel needs a modem to match the client side modem shown in

[23] Contention occurs when two or more users require access to the same medium. A Contention Ratio (C/R) is an oversubscription economy which assumes that not all users will need the service simultaneously. A C/R of 5:1 would assume only 1 in 5 users would use the service at any given time. The higher the contention ratio, the greater the number of users that may be trying to use the available bandwidth at any one time and, therefore, the lower the effective bandwidth offered during periods of heavy demand. C/R could take the form of the ratio of BIR (Burst Information Rate) to CIR (Committed Information Rate guaranteed to the customer). BIR is allowed only if it is available.

Figure 8. This is provided by the modem rack which provides 1 line card (modem) for each channel. From the VPN concentrator, there is access to the Internet through a selected ISP. As well there is access to the PNGARNet server farm. At present there is Web server for each institution to host its Web site, and a network wide Domain Name Server (DNS) to match IP addresses to host names.

Each client institution has secure access to the network via its own VPN channel which is accepted by the VPN concentrator with up to 50 channels available. Each channel needs a modem to match the client side modem shown in Figure 8 to change the digital data back into the form required by the new medium. This is provided by the modem rack which provides 1 line card (modem) for each client channel. From the VPN concentrator, there is access to the Internet through a selected ISP. As well there is access to the PNGARNet server farm. At present there is Web server for each institution to host its Web site, and a network wide Domain Name Server (DNS) to match IP addresses to host names. The development of the server farm has the potential to greatly strengthen the offerings of member institutions by sharing such facilities as a library database, and e-learning resources through a common Course Management System (CMS). Inter-university library loans could become possible as well as the sharing of taught units and inter-university accreditation.

Running costs per site

Clearly there will have to be monthly location and maintenance fees for collocated equipment at the Hong Kong NOC.

Design benefits

Internal security

Internal security issues are matters of great importance. It has been not unknown, for example, in quite eminent international institutions of higher education to have had students break into records of examination results and alter those records in their own favour. Clearly, resources available to particular users should be allocated on an as-needed basis. Resources which are vulnerable to misuse must be carefully isolated. All this can be achieved by internal security using what are termed Virtual Local Area Networks (VLANs). Users have access to their allocated VLAN and data passing between VLANs are strictly controlled using Access Control Lists (ACLs). Among the VLANs there will be one for the Vice-Chancellors, one for the libraries and one for the students, each group consisting of users from all member institutions.

Thus Virtual Local Area Networks (VLANs) will be established as needed. Access Control Lists (ACLs) control packet flow between VLANs thereby providing internal security. As a further security feature, all communications across the network occur within a Virtual Private Network (VPN) which uses encryption and tunnelling techniques to secure communications (See Figures 8 & 9). A VPN is essentially a dedicated private link is established on a shared internetwork.

Hong Kong co-located server farm

The advantages of the choice of the Speedcast[24] NOC at their Hong Kong location are also worthy of mention. Hong Kong is situated at a core node for submarine fiber-optic cables (see Figure 5 above) providing fast access to the major backbone carriers of the Internet. It is only one or two hops (gaps between Internet routers) from the US and the UK. The server farm can be remotely administered from one of the member institutions (DWU ICT Services, at least in the first instance). On-site technical support will be provided for hardware maintained on-site, hardware Redundancy, clustering used to provide Load Balancing and Fault Tolerance.

Network Operation Centre (NOC)

The NOC or data centre is a secure building site with administrators and support personnel, which is used to co-locate (rent space for) various types of servers (Figure 9), communications equipment, and security systems owned by the consortium. The NOC is designed to provide high availability, reliability, and scalability for mission-critical applications such as databases, groupware, email, on a 24-by-7 basis. This allows for centralised management, technical support, backup control, power management, protection from natural disasters, and general security. Advantage is being taken by PNGARNet to outsource these services to Speedcast Data Centre (NOC) which has a location in Hong Kong which will be accessed by client sites by high-speed satellite (ASIASAT 4) connection.

Services

PNGARNet will develop and grow as its advantages become more familiar and are better understood. Creative minds will explore, in the years to come, presently undreamt of uses of a technology still in its early stages. In the first instance, it is intended to provide email services for all users, Internet access for all users, shared access to full text databases, shared data stores and collaborations with other universities of the South Pacific. Further services as technologies mature and on-site equipment becomes available, include real-time videoconferencing, real-time online research capacity, and access to super computer computing power.

[24] See http://www.speedcast.com. SpeedCast is a satellite service provider operating in over 35 countries in Asia Pacific, Middle East and Africa. Speedcast operates on many different satellites in both C-band and Ku-band, and partners Tier 1 carriers for fiber requirements. SpeedCast and its partners worldwide provide services and 24/7 technical support.

Summary

Advantages to all PNG OHE institutions

By way of summary, it may be observed that the overall advantages to participating institutions and their members include access to databases at reduced cost as consortium members, shared research projects and inter-institution partnerships, increased professional communications both within PNG and internationally, reduced costs to each institution and increased facility for PNG academics to be represented and active internationally.

National benefits

This network will greatly elevate the level of computer literacy of all staff and students at PNG institutions of higher learning thereby reducing the digital divide which still exists even in developed countries. Students, later to become leading citizens in all walks of life will be exposed to state-of-the-art technology and information communication techniques.

In particular, national capacity will be developed by means of e-Learning centres for Government and non-government sectors, health online consultancies, services to provincial government centres, services to remote communities, and data gathering services in support of public service utilities such as schooling, and the police service.

Conclusion

This paper has endeavoured to provide an insight into the structure of the new satellite-based digital communications network to be known as PNGARNet which is presently operational but continues to develop and expand. This insight was also meant to highlight the advantages of the design for PNG as-well-as its cost effectiveness.

In its use by the various member institutions, enhancements for national education and research have been enumerated. The general democratic nature of the governing consortium has been described. The structures are now established, but the ultimate level of participation of any institution depends entirely on choice made by that institution. All aspects of maintenance and security of server-side equipment are provided by expert personnel at the nominated NOC owned by Speedcast and conveniently located in Hong Kong, a location which is well positioned to provide access to the wider Internet.

The structure leaves open the future possibility of developing learning material in electronic form, either as developed lecture material or material to be posted on the network using Course Management Software (CMS). It should be noted, however, that because of the lack of permanence and possible lack of peer review of this material, and because of its availability only when the user has access to a computer terminal, data in electronic form can never be assumed to be a replacement for hard copy printed material traditionally provided by text books or references housed in university libraries.

Finally, it should be noted that there will always be need for ongoing expert technical support for system maintenance, a challenge to present and future generations of IT graduates from our universities. This will not come easily and will be expensive. Equipment failure will always be with us. Satellites have a life expectancy of around 15 years and PCs of no more than 5 years.

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