A Proposal of a Low-cost IP-based Wireless WAN for Telemedicine

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1 Purpose

We have built an inexpensive IP-based Wireless WAN System linking with VSAT that combines Spread Spectrum and Time Division Multiple Access (TDMA) communications technologies. GATEWAY protocol offers the capacity to integrate, onboard the satellite, ground-based wireless WAN systems that are currently scattered over a wide geographic region. This paper discusses the design and the primary features (portability, low-cost) of the wireless WAN linking with VSAT for the purpose of building distributed small size of medical networks.

2 Background

AMINE

A group based at the Tokai University School of Medicine (TSJ: Telemedicine Society of Japan) built and operated an international medical network (AMINE) in the Asia Pacific region (Papua New Guinea, Fiji, Thailand, Cambodia, China, and Japan) from 1992 through 1996. The project entailed the free distribution of 24 VSAT stations that carry still images for medical use and real-time two-way audio transmission via ETS-V[1]. Our objective is to revive this project using the new IP-Based medical network.

3 Design and Prototype

3.1 System Concept

The system concept is shown in diagram 1. Wireless terminal’s transmission rate can go up to 2 Mbps given a frequency band at 22 MHz. Given this condition, VSAT can connect up to 4 Voice-over IP, ground-based wireless terminals (Client stations). An analog repeater type of satellite transponder for use is provided with a flat frequency, but is limited to ample electrical power that affect a data speed. For example, each VSAT data speed can be 512 kbps of UDP/IP with QPSK (SCPC) and networking of VSAT to VSAT communications with Hub, total 12 Mbps (24 channels $\times$ 512kbps) of transponder is estimated to be connected around a maximum of 30 VSATs based on past Japanese telemedicine data with Erlang B formula[2].

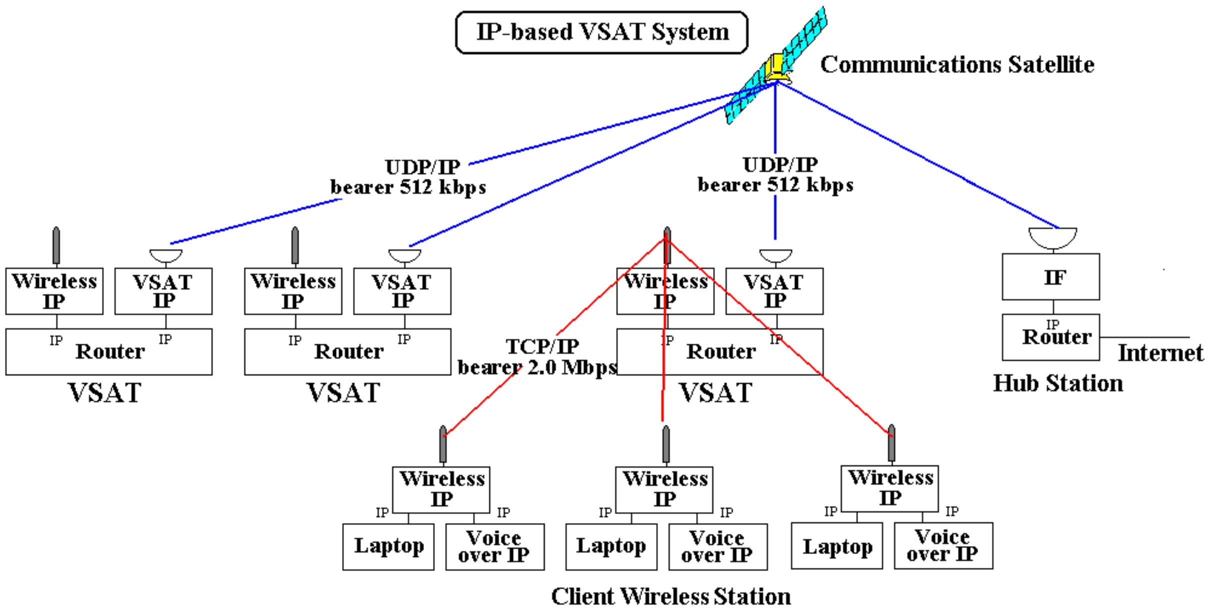

Diagram 1 – System concept

Voice-over IP refers to real-time audio conversation via the Internet. Providing VSAT with an IP-based GATEWAY feature of WAN enables VSAT to integrate distributed Internet networks onboard the satellite.

From the IP perspective, the basic principal of the GATEWAY feature is to distinguish one station's data from another, to separate and relay them, the rule is to multiplex. To accomplish these tasks, we use a multiplex hybrid - Code Division Multiplexing: Spread Spectrum and Time Division Multiplexing: TDMA (packet transmission). An ASIC Modem is essential for high-speed Spread Spectrum + TDMA signal processing. We selected the STEL-2000A, made by Stanford Telecommunications, Inc. This ASIC Modem is a DS- SS (Direct Sequence- Spread Spectrum) that uses coded Maximum length sequence. It is capable of offering 4-client station GATEWAYs by allocating 11 of 12 frames for data transmission, using the last frame for network management on TDMA's time axis. Adding TDMA to Spread Spectrum has the disadvantage of decreasing execution speed, requiring idling time for each packet frame. On the other hand, it also provides the advantage of error correction efficiency.

3.2 Features of STEL-2000

The STEL-2000 may be operated as a conventional half-duplex modern providing a modulated output at IF. Alternatively, it may be operated as a non-conventional, full-duplex modern providing a data- and spread-modulated signal at base-band (I & Q). Since the ASIC has only one NCO, which is used for demodulation, it is not possible to generate simultaneously a modulated signal at IF. In a typical application we expect that it would normally operate as a demodulator waiting to be polled. Only when a complete polling message was received would it configure itself as a modulator. The modulator functions include differential encoding, data modulation, and spread modulation. The demodulation functions include down conversion, and matched-filter detection, symbol synchronization, and DPSK data detection. The IF is limited by the maximum sampling rate (32 MHz) and the bandwidth of the signal. The limit is set by the need to avoid the aliased components present in any sampled-data system. STEL-2000A, the core of VSAT, and adjacent areas are shown in a block diagram (diagram 2). Chart 1 gives specifications for VSAT.

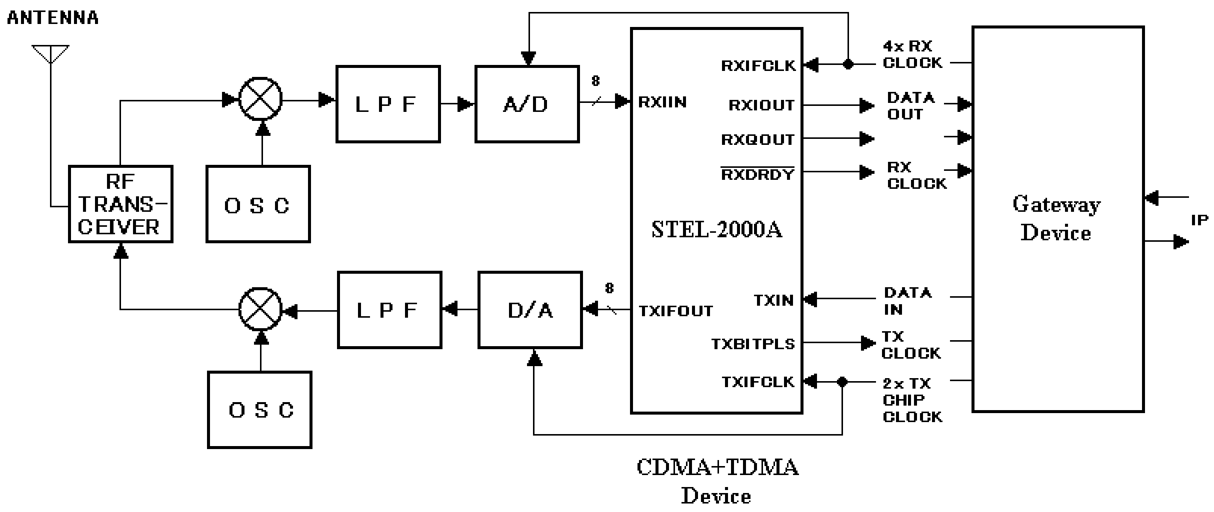

Diagram 2 – Block diagram of adjacent area of STEL-2000A

Specifications

Specification	RCR-STD33A standard (Japanese) for low-power data communications and wireless LAN systems
Modulation	SS-DS(Direct sequence spread spectrum)
Frequency	2.4 GHz Band (Japan: 2.483/2.485 GHz; FCC: 2.452/2.462 GHz)
Transmit power	10mW/MHz maximum
Modulation rate	2Mbps
Base band modulation	DQPSK
Link range	5 km (3.125 miles) maximum, line-of-sight Range will vary according to user environment
Interface	10BaseT(RJ-45 Normal)
Power requirements	AC100V/DC12V 1A (an AC/DC adapter is included)
Weight	Main unit (outdoors): 2 kg (2.2 pounds) Junction unit (indoors): 130 g (4.6 ounces)
Dimensions	Main unit (outdoors): 216 x 145 x 100 mm (8.5 x 5.7 x 3.9 inches) Junction unit (indoors): 117 x 32 x 100 mm (4.6 x 1.25 x 3.9 inches)
Protocol	IP
Rooting protocol	RIP2
DHCP server function	Yes

Chart 1. Specifications for IP-wireless terminal

3.3 Transmission Feature of IP-wireless terminal

3.3.1 Packet Frame Transmission

Packet structure entails a control header of 512 bytes and a data packet frame of 192 bytes fixed-length.

3.3.2 Driver-less Operation

Providing IP connections are available, conventional ground-based wireless terminals require dedicated driver software on the IP device connected to the client side PC. Because installing this driver is complex our device is provided with an Ethernet interface and does not require dedicated driver software to enable connections. All that is required is to simply connect the client PC subordinate to our device and run Internet Explorer on Windows.

3.3.3 Network Topology Management

The particular nodes sued (Both for satellite system: VSAT and ground-based wireless terminal: client) can flexibly accommodate changing network topology. Each node exchanges information concerning routing control with the host network, allocation of client IP addresses, fault monitoring, and environment settings, in order to manage the VSAT'S and the client station's network topology. Network topology information is allocated in the data frames. Additionally, nodes are loaded with ROM-executed features such as RIPV1, 2, DHCP Server, SNMP, and Telnet. RIPV 1, 2 are equipped with information exchange features on routing control and are designed to implement smooth connections with host networks. The DHCP Server feature performs dynamic IP allocation to the client side PC, enabling IP connections without requiring the average user to bother with tedious configuration tasks. SNMP enables monitoring of network operations using standard management software. The Telnet feature makes it possible to change settings remotely within a network and/or to perform wireless link verification from remote geographical locations. For instance, a physician in a developing country may not necessarily have much knowledge of network communications. But this poses no problems, since a supervisor in the developed country can remotely verify fault status and implement fault-countering measures and/or configure by-pass routes from the NOC side.

3.3.4 Antenna of the IP-wireless terminal

The prototype receiver/transmitter component and antenna are shown in the photographs. This S-band antenna is a helical antenna 30 cm in length, with a gain of approximately 14 dBi, can provide 15 km distance connection with each other. Another test result was 63 km with 1.2m dish and 27 elements Yagi.

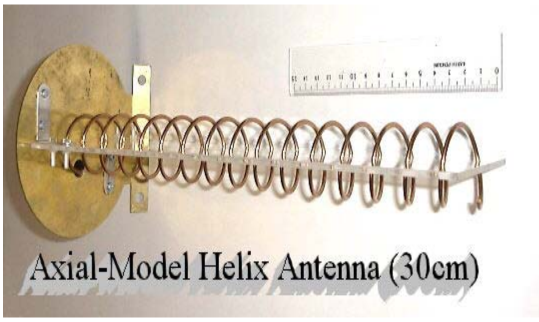

Diagram 3 Helix antenna

Diagram 4 – Inside of IP-wireless terminal

4 Discussions

4.1 How to reduce running cost of Telemedicine

All telemedicine projects face the challenge of minimizing communications costs. We believe the following three methods will effectively reduce communications costs:

1) Preparation of an independent circuit
2) Universal service finance
3) Internet Protocol Telephony through open competition

The first option is a special circuit dedicated to telemedicine (hereinafter referred to as a "dedicated circuit"). The PEACESAT project led by the University of Hawaii, which was allowed to use an ATS-1 satellite transponder free of charge, had great long-term success. The IP-based wireless WAN system studied in this paper does not require the payment of carrier charges. Once the wireless equipment has been installed, it can be used for an extended period without maintenance, unless the antenna is damaged or destroyed by hurricane or flood.

4.2 Economic Feasibility of hardware

The outstanding trait of IP-based Internet is its ability to connect all connection devices scattered across a network. In regions such as developing nations where ground-based infrastructures are poor, this permits installation of a low-cost infrastructure using ground-based wireless WAN systems. If VSAT can be designed to provide GATEWAY compatibility comparable to ground-based wireless WAN systems in order to implement such an infrastructure, satellite and ground-based systems can be integrated with relative ease. We believe that building low-cost IP networks in developing nations will require the widespread use of ground-based wireless WAN systems. VSAT is imperative in connecting these networks together to build larger and more complete networks.

Sharing the ground-based wireless WAN system's hardware can hold down VSAT's development costs. Diagram 5 shows the cost per VSAT when up to 128 VSATs are purchased and ground-based wireless terminals (clients) are respectively connected to each VAST. For example, if 4 VSAT stations were purchased and each VSAT connected 4 clients, the cost of a VSAT station (1 VSAT device + 4 client devices) would be approximately 20,000 U.S. dollars. The price declines gradually as the number of VSATs increases, although the satellite's transponder power supply and frequency band do have eventual limits.

When we operated AMINE via ETS-V from 1992 to 1996, we focused on implementation of real-time teleconferencing. Then came the astonishing growth of the Internet, with its store-and-forward transmission foundations. With the current telecommunications satellite, our aim is to build a flexible network by fusing VSAT and ground-based wireless terminals. Achieving this would make it possible to submit medical images to specialists on the Web, to provide and receive consultations, and enable discussions among physicians via voice-over IP, using inexpensive devices.

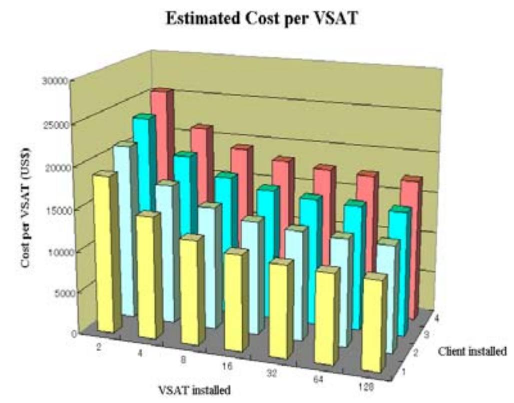

Diagram 5 – Estimated cost per Wireless terminal (client) and VSAT

5 Conclusion

We have built an IP-based wireless WAN prototype linking VSAT to be used as an inexpensive ground station, which is capable of integrating, onboard the satellite, geographically scattered computer networks. We believe wireless WAN and multiple VSATs will enable flexible and multi-dimensional connections over developing nations.

Acknowledgements

We would like to express our appreciation to Mr. Hiroshi Juoji of Tikai University, and to Mr. Masuhisa Ta of Tasada Works Inc., for their cooperation in the field experiment.

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