SCAN™ White Paper

Scanned Channel Assigned Networking:

A Unique Approach to High Efficiency Bandwidth Management

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SCAN Conceptual Description

SCAN is LinkSat's patented satellite bandwidth management solution. It is a fully automated on-demand satellite bandwidth management tool that utilizes local spectral analysis at each network node to determine availability of bandwidth for set-up of point-to-point and point-to-multipoint satellite carriers. Spectral analysis is employed at all of the satellite network sites (or access terminals) to track carrier activity in a pre-determined segment of satellite bandwidth. Each site in a SCAN network independently monitors carrier activity and, using the spectral activity data, automatically and autonomously makes decisions on when and where to transmit carriers and which receive carriers to acquire within a pre-defined segment of bandwidth.

The concept is equivalent to an operator at a remote site constantly watching a spectrum analyzer screen. The operator first determines when bandwidth is needed by that site, then, on the basis of spectral activity, determines which spectrum segments are unoccupied, selects one of those segments, tunes a modulator to that frequency, then turns on a transmit carrier. The receiving sites all see the new carrier and tune an available demodulator to the frequency if one is available and if the carrier observed is in their channel map. The receiving sites all check to see if that carrier contains data for their local network. If it does not, they release the demodulator. This places the network management smarts at the end points of the circuit. This distributed network processing architecture means that no centralized network manager is necessary, which.

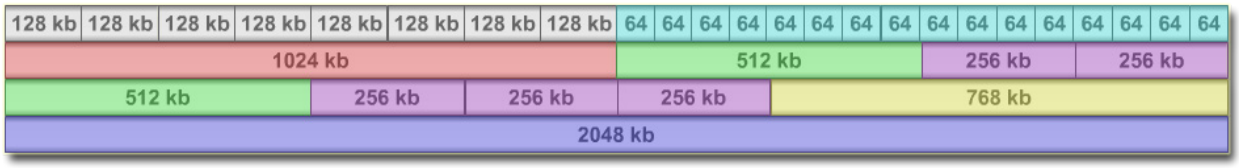
The main benefits of the SCAN architecture are:

- Hub or hubless network topologies possible - analogous to Client / Server and Peer-to-Peer networking
- Multiple network architectures supported - STAR, Mesh or Partial Mesh networking, with multiple hubs if needed
- Minimal network software and hardware investment needed - allows cost effective deployment of small networks
- Distributed processing – network management is distributed throughout the remotes minimizing single point failures
- Ethernet switch in-the-sky - enables full multipoint dynamic routing over satellite
- Reduced capital costs - improves overall network reliability and eliminates expensive hubs and high start-up costs

The actual carrier sense and collision avoidance utilized in SCAN is similar to Carrier Sense Multiple Access- Collision Detection (CSMA-CD). The major difference between SCAN and CSMA-CD is that SCAN works in an environment with multiple carriers operating simultaneously over a satellite frequency band. Therefore, an appropriate name for the technique is Carrier Sense-Frequency Division Multiple Access-Collision Detection (CS-FDMA-CD).

CHANNEL ACCESS METHODS / MULTIPLE ACCESS PROTOCOLS		
CHANNEL BASED	FDMA	OFDMA, WDMA, SC-FDMA
	TDMA	MF-TDMA, STDMA
	CDMA	W-CDMA, TD-CDMA, OFHMA
	SDMA	HC-SDMA
	PDMA	
	PAMA	
PACKET BASED	Collision Recovery	ALOHA, Slotted ALOHA, R-ALOHA
	Collision Avoidance	CSMA, CSMA/CD, CSMA/CA, MACA
	Collision Free	Token Ring, Token Bus
CHANNEL & PACKET BASED	SCAN	CS-FDMA/CD

When the network is initially configured, a set of allowable channels within the satellite spectrum is defined. These "channel maps" are a set of definitions consisting of frequency assignments, data rates, FEC rates, and modulation types of allowed carriers. SCAN has the ability to determine carrier frequency, power, and occupied bandwidth. A simple channel map look up table allows the software to determine what the data rate and FEC rate are for a received carrier, and what data rate and FEC rate are needed for a transmit carrier.



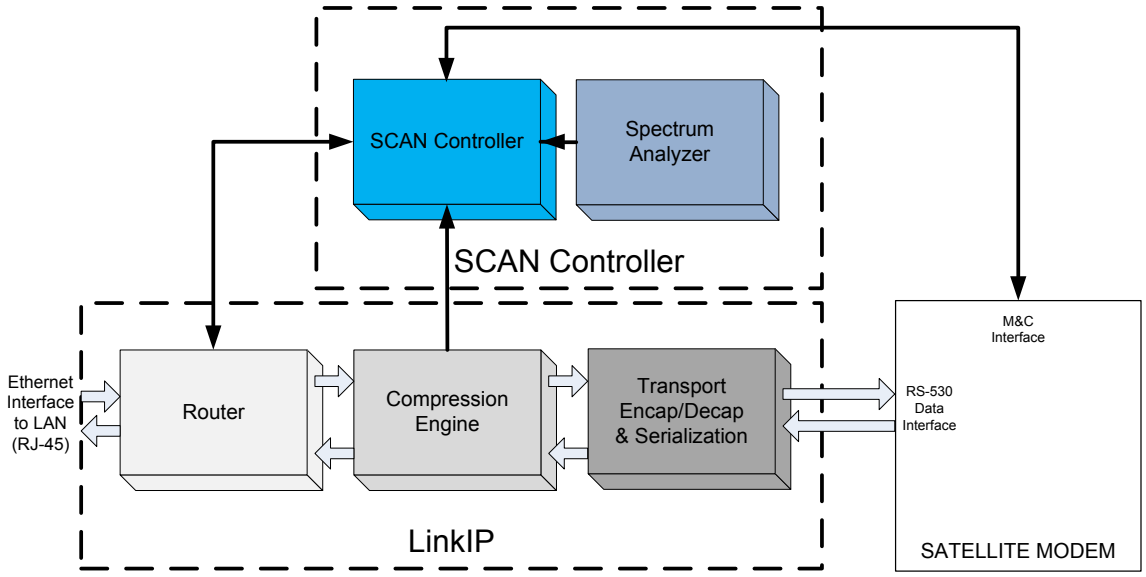
SCAN Channel Map Example

The SCAN transmit sequence is initiated by activation of an application at the local network, for example a videoconference is started, or a VoIP call is dialed. When data packets (VoIP, IP video, FTP, MPEG4 video, etc) enter the LAN port of the router, the LinkIP looks for an available spectral channel appropriate for the service to be transmitted, and, when it finds one, it tunes a modulator to the frequency and sets the appropriate data rate/ FEC, and then begins to transmit. When data ceases entering the LAN port, or a local application is terminated, SCAN automatically commands the modulator to turn off the transmit carrier.

When a carrier is transmitted to the satellite by any site in the network, the SCAN spectrum analyzers at all sites in the network will detect it. If the carrier channel is registered in the channel map of a particular site, the LinkIP will automatically tune a demodulator to the carrier frequency and data rate, and will acquire the carrier. The data is then demodulated and decompressed, each packet is inspected by the router, and those packets destined for its base station are routed out the LAN port. All received packets that are destined for other sites are discarded by the router. If the carrier has data for the local network, it will continue to downlink the carrier and route packets through its LAN port. If not, it will disregard the carrier and wait for a new event. The remote LinkXX routers can be equipped with multiple demodulators that can be used for multiple simultaneous circuits. Additional demodulators can also be used as backup demodulators for site redundancy.

The services platform with which SCAN interfaces is called the LinkXX. It is a powerful custom router that plays an important role in the bandwidth acquisition process for IP protocol networks. The router supports all commonly used routing protocols, including static routing, OSPF, BGP, RIPv1/v2, Multicast (IGMP), Unicast, Broadcast, DVB-MPE, and SIP. The router also provides a powerful data compression engine (LinkShrink), as well as a UDP client and server. See LinkSat's white paper entitled *LinkXX Capabilities* for more information on the LinkXX.

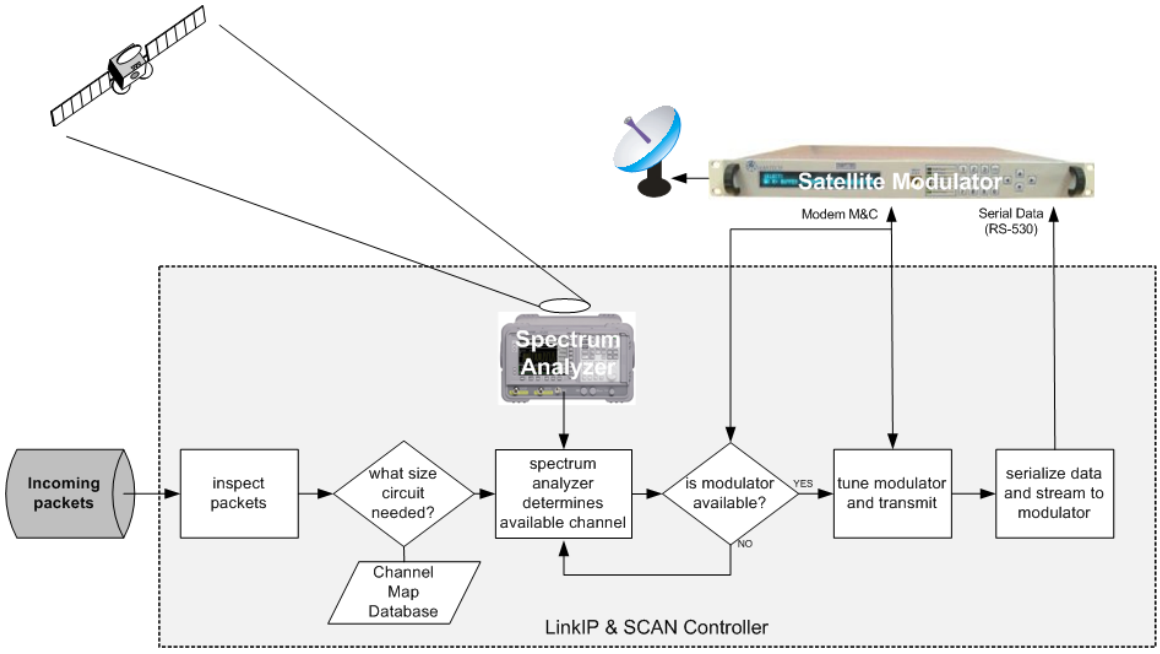
The actual spectrum analyzer (scanner) hardware resides in the SCAN controller, and is a DSP FFT that captures signals in the band of interest. The scanner, in effect, constantly monitors the spectrum in real time. An initial spectral snapshot is sent to system memory when the SCAN controller is initialized. The spectral information is processed by the scanner, which then determines carrier power and bandwidth. It then compares that data with its channel allocation map. The channel map is a set of pre-defined allowable carriers that are programmed in software. Each spectral scan is very fast, in fact, an 80 MHz segment is scanned in less than 5 milliseconds. Hence, the LinkXX has a virtual, real time snapshot of the spectrum of interest. This data allows each site to determine where a carrier may be transmitted without interfering with another transmission.



SCAN / LinkIP Functional Block Diagram

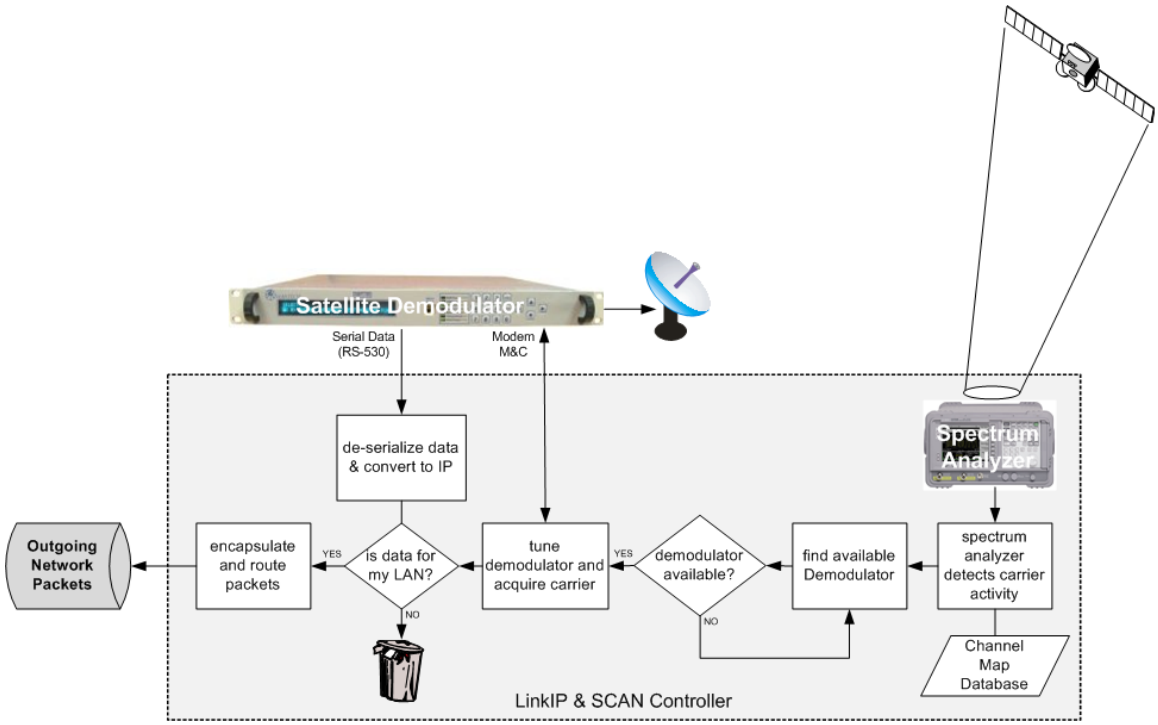
SCAN operates in basically the same way for both transmit and receive modes. Transmit SCAN determines bandwidth availability, and controls the modulator for activation and deactivation of carriers. Receive SCAN mode tracks new carrier activity in the spectrum and determines who is transmitting each carrier and who is supposed to receive it by tuning local demodulators to those carriers. The LinkXX will accommodate multiple demodulators for this purpose. A single SCAN controller will operate in both modes simultaneously.

In transmit SCAN mode, the router makes the decision on when bandwidth is needed and initiates the SCAN process. The SCAN controller provides the interface between the router elements and the satellite modulator and demodulators. Using the spectral data and a randomization routine, it determines an appropriate transmit channel for the modulator. It then tunes the modulator to that frequency, sets a data and FEC rate, and turns on the carrier.



SCAN Transmit Process

In receive SCAN mode, the router determines whether IP packets acquired by a demodulator are destined for its LAN. If they are, it keeps the demodulator engaged until the transmission is complete then releases the demodulator. If the packets are addressed for another site, it discards those packets received and releases the demodulator immediately.



SCAN Receive Process

Collision Avoidance and Recovery

One of the problems associated with multiple access schemes is that of collisions, or double illumination of the space segment. Multiple safeguards have been built into SCAN to avoid double illumination of carriers. The primary safeguard is SCAN's ability to measure spectral density.

If a station activates a carrier and SCAN subsequently detects that the power in its channel has gone to approximately double its normal density (3 dB), it will sense that a collision has occurred. It will immediately terminate the transmission and initiate another search for an available channel.

Another and even more accurate way to recuperate from a collision, and to have early detection, is to use a timing window. Since the SCAN controller can accurately determine the round trip time (RTT) from the local router to the satellite and back, it can tell when its carrier is the first to arrive in a selected channel slot. The detection takes place on the basis of which carrier arrives first. If a carrier arrives in less time than the RTT for a local transmission, then the controller knows that carrier is not its own transmission. In that case, it will immediately cease transmitting and start the channel selection process again. If it receives a double illumination after its timing window has expired, then it knows that it was the first to transmit and leaves its carrier on the air

and waits for the other station to back off. The timing window can be adjusted but +/- 10 milliseconds is generally adequate.

The only exception to these rules is when an emergency service (e.g. 9-1-1) is used. In that case, the LinkIP will use any available channel and will double illuminate a channel if none are available. It will stay on the air until everyone else back off of that channel. This is a timed event in the LinkXX such that if a double illumination persists for more than a programmed amount of time (normally 2 seconds) then anyone transmitting on that channel will mark it as an emergency channel temporarily.

The other important factor in collision avoidance is to prevent collisions before they happen. In the SCAN system, this can be done by randomizing the selection of transmit channels so that all competing stations using the bandwidth will be evenly distributed in time and frequency over the entire bandwidth.

Space Segment Channel Allocation

A critical element to SCAN is space segment channel allocation. The available bandwidth needs to be allocated into discrete channels for SCAN to function efficiently. A channel scheme for a network needs to be defined, and then programmed into each LinkXX in the network. Each channel is defined by information rate (IR), FEC rate, and modulation type. Occupied bandwidth is calculated automatically by the scanner on initialization.

Channels can be set up so that the spectrum is sub-divided many times, allowing several channel definitions for a range of bandwidth. If a smaller channel is occupied, SCAN will not place a larger carrier in that slot. For example, if a 128 kb/s carrier is active, SCAN will not place a 512, 768, or 1024 carrier in the slots above that active carrier.

When a LinkXX router senses incoming data on its LAN port (or serial port, depending on how the LinkXX is configured), it determines the data's Type of Service (ToS) and Quality of Service (QoS). ToS determines what size carrier to transmit. ToS bits are used to select a range of bandwidth for a particular service. Up to six ToS levels can be defined in the LinkXX. ToS can be keyed on service type, destination, origin, packet size, or on other criteria. A minimum acceptable bandwidth and a maximum allowable bandwidth are defined for each ToS. The LinkXX then compares the ToS definitions with spectral occupancy data provided by SCAN to determine which channels are available for the service requested. QoS determines the priority of each service. The LinkXX router uses QoS bits to determine Queuing Priority both when setting up a new circuit and when a circuit is already active.

SCAN can detect both spectral density and occupied bandwidth. When searching for an available channel, SCAN first looks for a channel that fits the minimum acceptable bandwidth criteria. If one is not found, it continues to work its way up to the maximum allowable bandwidth channels until it finds an available channel.

See LinkSat's website (www.linksat.com) for LinkXX data sheets and related application notes.