A BRIEF NOTE PROPOSING NON-ALOHA ACCESS TECHNIQUES FOR PACSATS

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ABSTRACT

Carrier-sense multiple-access (CSMA), as used in most terrestrial packet radio networks, is not efficient for low-Earth orbiting store-and-forward packet satellites (PACSATs). This note describes a simple time-division multiple-access protocol for PACSATs. A procedure is proposed for early experiments on the UoSAT-D Packet Communications Experiment (PCE) transponder, using AX.25 as the link protocol with satellite-controlled TDMA arbitration.

1. ALOHA UPLINKS

A low-Earth orbiting PACSAT will appear to users as a PBBS on a very high hill, and it will have the same access problems as a hilltop digipeater or PBBS: the PACSAT will hear many stations, but the user stations will not hear one another. The groundstations are all hidden terminals, and CSMA will not stop them from transmitting simultaneously on the satellite uplink. The uplink will tend to look like an ALOHA channel, modified by the FM capture effect. (Capture effect will increase throughput, as stronger stations override weaker ones during collisions on the uplink.) In the classical analysis, where all packets in a collision are destroyed, maximum throughput of an ALOHA channel is 18%, and this begins to drop toward nil when the channel is overloaded. See Tanenbaum (Ref. 1) for the bad news.

A simple solution to this problem - proposed for amateur PACSATs and used successfully on FO-12 - is to have several uplink channels and a single downlink. The ratio of 4 uplinks to a single downlink brings our theoretical maximum uplink throughput to 72% of the data rate. (This leaves some downlink bandwidth free for telemetry broadcasts, acknowledgements and multi-destination messages.) This simple solution works, but at a price. The satellite must have four data demodulators and four receiver IF chains, and the PACSAT computer must have the power to handle 4 uplinks simultaneously. Over lightly-populated areas, there may be only one station per uplink, and the combined uplink data rate will exceed the the theoretical 'maximum' throughput by a factor of five. Although this is not a problem for the new generation of PACSAT CPUs, it will be when data rates rise significantly above 9.6 kbps. From feast over the boondocks, we get famine in the cities; when the satellite is over a heavily populated area, the independent ALOHA channels will still tend to get overloaded, and throughput will fall. This is especially true when the satellite first comes into range of a population center and everyone starts trying to send messages at once.

Even if we accept these performance problems and use four uplinks per satellite, frequency allocation and band crowding will drive us to find more efficient access techniques. Relatively low Doppler shift make the VHF and UHF bands the natural home for low-Earth orbiting satellites, and soon we won't be able afford four VHF uplinks for every PACSAT. FO-12 and Microsats A & B already occupy twelve 2-meter user access channels. Hoping to ease this crowding problem, the Packet Communications Experiment (PCE) on UoSAT-D will be used to experiment with non-ALOHA techniques on a single uplink.

2. OTHER ACCESS TECHNIQUES

There are many multiple access techniques other than ALOHA, some of which are addressed in the references. When considering these schemes, keep in mind that the PACSAT environment is a new one for Amateur packet networking, because the satellite itself is a reliable, powerful central node which can form the hub of a non-ALOHA network. This central processing power should manage the available bandwidth efficiently and fairly. We should make sure that some traffic gets through even when the 'offered load' is high, and that small, weak stations don't get out-gunned by stronger ones.

Busy tone multiple access (BTMA) was considered. Whenever the uplink is bwsy, the satellite would transmit a 'busy signal' on the downlink telling other stations not to begin transmitting. We could not find a way to include a reliable, up-todate busy signal on the downlink without great complication and/or increased downlink bandwidth. We also ruled out spread-spectrum techniques such as code-division multiplexing, although these may play a role in future amateur packet satellites.

We decided to concentrate on time-division multiple access (TDMA) for the time being. The UoSAT-D PCE will act as master station and groundstation PCs or TNCs will be the slaves. 'TDMA' does not imply that groundstations will have to be locked to a common time base, transmitting their data in precisely synchronized bursts. The term indicates that the PCE will manage groundstation access by dividing the uplink into time slots, with different slots for different uses. We will attempt to adapt the TDMA system to AX.25 link layer so as not to completely remove the installed "user base" who have AX.25 TNCs. (At the very least, KISS TNCs could be used as HDLC frame generators.)

Harold Price first drew my attention to such a scheme in a study report about the Swedish MAILSTAR satellite, and subsequent conversations with Phil Karn developed the ideas and the analogy to HF DX operations.

3. THE PCE ACCESS SYSTEM

All communications between groundstations and the UoSAT-D PCE will be computer-to-computer transfers. Message system operations like List, Read, Send and Delete will be high-speed, full-duplex transactions between the PCE and a groundstation computer. The human interface -which presents message lists clearly, compresses and expands text messages, and provides the user with a nice menu - will be in groundstation software. While this shifts the user interface from one satellite into thousands of user computers, we believe

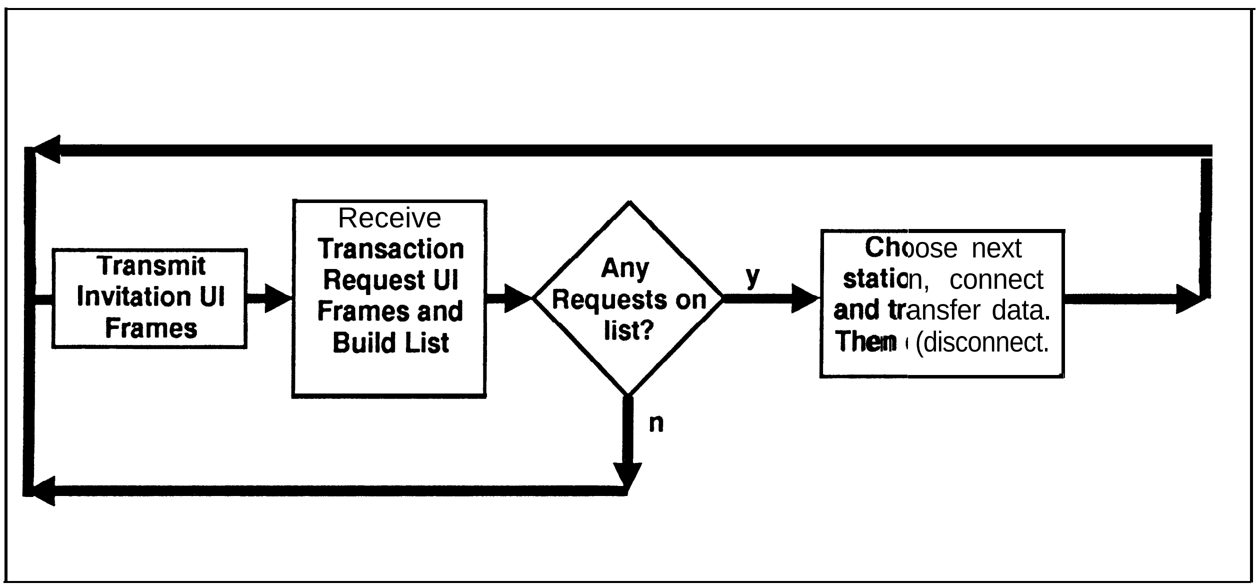

Fig. 1 - Flow Chart of TDMA with ALOHA Request Period

that the groundstation computer has more time and memory for these tasks than the satellite computer does.

The protocol described below is shown as a flow chart in Figure 1.

3.1 Pile Up Operation

Whenever the PCE is idle, it will transmit an **Invitation** frame which invites groundstations to reply. This will be an AX.25 UI frame identified by its contents and/or a special PID. Upon hearing this, the groundstation computer will start a random **backoff** timer, after which it will transmit a **Transaction Request** packet on the **uplink.** When the PCE hears one of these **Transaction Requests,** it connects to the station heard and begins a message transaction using a standard **AX.25** link. When the transaction is complete, the PCE goes back into the idle state.

This protocol divides **uplink** time into two portions: an ALOHA portion during which all groundstations can transmit, and a contention-free portion during which one groundstation has the entire **uplink** to itself. The theoretical maximum throughput of this system and is:

1 - (ALOHA time **/** total time).

3.2 List Operation

The PCE will probably hear Transaction Request frames from several stations during the ALOHA window. It will keep a list of stations heard and then work them one at a time in successive contention-free transactions. The **Transaction Request** frame transmitted by a groundstation will **carry** information to help the PCE selection algorithm choose a station for the next transaction. A few factors which might be included in a priority scheme are:

- the length of the requested transaction,
- message priority,
- groundstation priority (higher for command stations or emergency stations),
- time until groundstation loss of satellite,
- time until next acquisition of satellite at this groundstation, and
- time since last transaction with this groundstation.

Obviously, the choice of priority factors and the calculations made by the PCE determine how the available pass time will be shared amongst many groundstations trying to use the PCE. Now we can start tweaking. Priority factors can be optimized to give greater throughput, greater equality of access, more efficient use of groundstation transmitters, etc. They could even be dynamically modified by an “expert system” in the PCE. This certainly beats the complete lack of "**tweakability**" available in the ALOHA system.

3.3 Token Passing

The TDMA technique described here can also be viewed as a token passing protocol. The satellite always passes the token to a groundstation, and the token will revert to the satellite when a transaction is completed or a connection fails. In a fullduplex environment, connection timeouts can be quick, increasing efficiency of the token passing. Efficiency will also depend on variables such as groundstation transmitter keying times, average message length, the priority algorithms and the RF link quality.

4.0 CONCLUSION

A successful **TDMA/Token-passing** protocol for PACSAT access will promote efficient use of **uplink** channel RF bandwidth and make best use of satellite on-board computing power. The transaction-based scheme proposed here could have several advantages over ALOHA:

- Weak stations and strong stations compete for throughput on an equal basis.

- Protocol variables can be adjusted to optimize a chosen parameter.

- Even when the offered load is much greater than can be handled by the uplink, some messages will get through.

The UoSAT-D Packet Communications Experiment will provide a platform for protocol experiments, not simply a communications service. The multitasking operating system (Quadron Communications Facility - qCF) which is being developed for UoSAT and Microsat will be an ideal environment for these experiments. Its high-level language support will speed development and debugging of protocol software, and a multi-tasking system keeps experiments away from spacecraft housekeeping tasks which will also be running on the PCE.

At UoS we are now finalizing PCE hardware design, while Harold Price and Skip Hansen are modifying qCF for spacecraft use. Applications software development will begin with spacecraft housekeeping, a mailbox, and the simple protocol outlined above. Groundstation software will be developed simultaneously, and we would like to have the entire system operational by launch. If the launch is in January, as currently scheduled, this will be tough (read "impossible"), but if the launch is delayed until June, there is hope.

REFERENCES

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