The L*IP Access System

**L*IP Satellite System**
- Prototype built for ESA, ARTES-5 contract
- Meshed MF-TDMA, over GEO
- Optimized for IP
- QoS
- DAMA
- MF-TDMA modem supports up to 4 Msymb/s
- QPSK, Turbo codec
- Fade mitigation techniques

**A Star Satellite Network, e.g. DVB/RCS**

**A Satellite Network with Meshed Topology, like L*IP**

**Comparison Star versus Meshed Topology in Satellite Networks**

Problems of star topology with DVB as forward channel:
- Fixed allocation of forward / return bandwidths
- Double hop for communication between 2 user terminals
- Twice the delay and twice the bandwidth
- Considerable large minimum bandwidth for DVB
- Expensive hub, even for small networks
- But: Receivers in terminals are cheap (mass market)

Meshed: flexible bandwidth allocation in forward and return
- Single hop between slaves
- But: slaves are more complex

**Reference Scenario of the L*IP Meshed Satellite Network**
Subdivision of the Satellite Resource in Time and Frequency (2)

- Carriers can have different size: 1, 2 or 4 Msymb/s
- Support of stations with different equipment (antenna, amplifier)
- For example: a low cost station can only transmit on a 1 Msymb/s carrier

Subdivision of the Satellite Resource in Time and Frequency (3)

- TDMA frame length: 20ms
- Time slot length 125us
- \( \rightarrow \) 160 slots per frame
- Bursts length in integer multiples of the slot length
- Bursts can be 1 to 159 slots long
- Efficiency increases with the size of the burst!

The Allocation Plan

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Multiplexing on the Satellite (or: How can we increase the burst size?)

Virtual Connections (VC) = IP Packet Flows
defined unidirectional;
specified by TX+RX station and QoS parameters

Pipes = Burst Flows
multiplexes of VCs
specified by TX station + RX station
Connection-Oriented Flow Identification

Multiplexing of different kind of traffic to different station into a single burst

Demand Assignment Multiple Access (DAMA)

Principle Architecture of a Terminal/Station

Traffic Queuing

Packet Switching

IP packets are switched to associated VCs, based on QoS class
Routing (receiver station)

Traffic Handling in a Terminal

Traffic Queuing

Packets wait in queues until BW is available (DAMA)
Different queues for different QoS classes,
High priority traffic may “overtake”
Packets are dropped, if incoming traffic rate is higher than available BW
Traffic Policing with the Token Bucket Algorithm

- Execution of QoS parameters
- TMR: Traffic mean rate
- MBS: Maximum burst size
- Incoming packets may pass the server, if enough tokens are available
- Traffic bursts up to MBS are accepted
- On the average, traffic rate is limited to TMR

Traffic Scheduling / Multiplexing

- Question: Which queue should be served next?
- Decision based on QoS parameters of the VC

Fragmentation & Reassembly (Encapsulation)

- Burst length is in most cases different from IP packet length
- IP packets have to be fragmented at the transmitter and reassembled at the receiver
- Encapsulation introduces additional overhead

TDMA Burst Format

- Preamble
- Burst Payload
- Guard Time
- TDMA Burst

ATM/AAL5 Encapsulation

- UU User to user indication 8 bit
- CPI Common part indicator 8 bit
- Length Length of payload 16 bit
- CRC Cyclic Redundancy Check 32 bit

ATM Adaptation Layer 5 (AAL 5)
**Format of the ATM Cell**

- 5 byte header
- 48 byte payload

<table>
<thead>
<tr>
<th>VPI</th>
<th>VCI</th>
<th>PT</th>
<th>CLP</th>
<th>HEC</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>16</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

- **VPI**: Virtual Path Identifier (12 bits)
- **VCI**: Virtual Circuit Identifier (16 bits)
- **PT**: Payload Type (3 bits)
- **CLP**: Cell Loss Priority (1 bit)
- **HEC**: Header Error Control (8 bits)

**Unidirectional Lightweight Encapsulation (ULE)**

- **PDU** (Packet Data Unit)
- **SNDU** (Sub Network Data Unit)

**SNDU Format of ULE**

- **D**: Destination address present flag (1 bit)
- **length**: Length of the PDU (15 bits)
- **type**: Type of the PDU (16 bits IANA EtherType)
- **PDU**: Protocol Data Unit
- **CRC-32**: Cyclic redundancy checksum (32 bits)

**Low Overhead Encapsulation (LOE)**

- **SNDU** (Sub Network Data Unit)
- **PDU** (Protocol Data Unit)

**LOE - SNDU Format**

- **type**: Protocol Type (optional)
- **CRC-32**: Cyclic redundancy checksum (32 bits)

**LOE - Fragment Format**

- **VCD**: Virtual Connection Descriptor
- **BoS**: Begin of SNDU
- **EoS**: End of SNDU
- **LEN**: Length of payload in Bytes
- **HEC**: Header Error Control

- **VCD** (4 bytes)
- **BoS** (4 bytes)
- **EoS** (4 bytes)
- **LEN** (11 bits)
- **HEC** (1 bit)
- **data** (1-2047 bytes)
Comparison of ATM, ULE and LOE

ATM is due to its large header compared to its small body inefficient.

ULE is nearly as efficient as LOE, but can only support burst sizes that are multiples of the MPEG-2 cell size → results in efficiency problems with VoIP traffic.

LOE is most efficient and supports any burst size → fits into the allocation plan grid with fixed slot sizes.

Calculation of the Total Bandwidth

Calculation of the signaling overhead (ref burst, allocation plan, BW requests)
Calculation of the burst overhead (unique word, guard time)
Calculation of the encapsulation overhead (fragment header, SNDU overhead)

Assumption:
Each active pipe is assigned one burst per frame.

How many pipes do we need ?

\[ N_{\text{pipe}} \geq \frac{k \cdot N_{\text{receiver}} \cdot N_{\text{burst}}}{N_{\text{ch}} \cdot N_{\text{freq}}} \leq 1.5 \]

Note that this is a lower bound on the number of pipes
In practice, 2-3 pipes per station are realistic.

Signaling Overhead

\[ O_{\text{sig}} = \sum \left( L_{\text{ref}}, L_{\text{AP}}, L_{\text{BWreq}} \right) \]

\[ L_{\text{ref}} = \text{const} \]

\[ L_{\text{AP}} = N_{\text{ch}} \cdot N_{\text{freq}} \]

\[ L_{\text{BWreq}} = N_{\text{pipe}} \]
**Signaling Overhead**

- Available bandwidth per station [kbit/s]

**Burst Overhead**

- Preamble
- Burst Payload
- Guard Time
- TDMA Burst

- Average length of Bursts
- Equivalent overhead bits

\[ O_{\text{burst}} = \frac{L_{\text{burst}}}{L_{\text{burst}} + b_{\text{burst}}} \]

**Burst Overhead (2)**

- Number of bursts per second
- Number of frames per second
- Signaling efficiency

\[ N_{\text{burst}} = N_{\text{burstf}} \cdot N_{\text{burst}} \]

\[ L_{\text{burst}} = \frac{\eta_{\text{burst}} \cdot R_{\text{burst}}}{N_{\text{burst}}} \]

**Burst Overhead (3)**

- Burst payload [bytes]

**LOE - Overhead Calculation**

- Average length of PDU
- Number of SNDU overhead bits
- Average number of fragments per PDU
- Overhead bits of fragment header
- Average length of burst
- Burst overhead bits

\[ n_{\text{sgh}} = \frac{L_{\text{PDU}} + b_{\text{PDU}} + 1}{L_{\text{burst}} - b_{\text{burst}}} \]

\[ O_{\text{LOE}} = 1 - \frac{L_{\text{PDU}}}{L_{\text{PDU}} + b_{\text{PDU}} + b_{\text{sgh}} \cdot n_{\text{sgh}}} \]

**Total Overhead Calculation**

- Signaling efficiency
- Burst efficiency
- LOE efficiency

\[ O_{\text{tot}} = 1 - \eta_{\text{sgh}} \cdot \eta_{\text{burst}} \cdot \eta_{\text{LOE}} \]