New trends in satellite communications
Presentation summary

- INEO E&S Aeronautical Export Department
- Satellite access analysis
- Anticipating the future
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INEO E&S Aeronautical Export Department

→ INEO E&S designs, builds, installs and maintain Information and Communication Systems
INEO E&S

At a glance
Skills – Fields of activities

Infrastructures
- Power stations
- Solar power systems
- Secured electrical distribution
- Airfield lighting
- Monitoring & Control
- Navigational Aids (VOR-ILS-DME-NDB-DF)

Communication Systems
- VHF, HF, MW, V-Sat Communications
- LAN / WAN Networks
- Secured optical fiber networks (data collection around the runway)
- Remote VHF stations
- Monitoring & Control

Air Traffic Control
- Voice Communication Switching System (VCSS)
- Meteorological Systems
- AFTN / AMHS switch
- Aeronautical Information Systems (AIS)
- Time Synchronisation
- Recording Systems
- ATIS / D-ATIS
- Integrated Consoles
- 3D tower simulators
Scope of work

Aeronautical System Integrator

- Project Management
- Engineering / Detailed design
- Equipment procurement
  - Integration
  - Overseas Transport
  - Installation and Commissioning
    - Training
    - Maintenance
The strength of an expertise dedicated to the customer

A multidisciplinary technical expertise for the benefits of the customer:

- Pool of Aeronautical Experts
- Pool of Telecommunications Experts
- Software development engineers
- Design department
- Integration facilities
- Partnerships with strategic suppliers
INEO E&S develops its own products dedicated to the Air Traffic Control world:

**Concerto Voice Communication Switch**

**3D Tower simulator**

**Voice@net Voice Communication Switch Simulator**
VHF coverage and VSAT network for INAC (Venezuela)

International Civil Aviation Organization (ICAO)

Supply, installation, commissioning, training of the technical staff of the civil aviation in order to implement a VSAT network of 29 stations and 8 VHF stations

- VHF radio coverage studies, design of the VSAT network and of the microwave links
- Interconnection of the VSAT system with the Radar, VHF, AFTN, ATN and ATS/DS voice switch
- Monitoring and control of all active equipment from two geographically separated centers
- Turnkey solution including the provision of space segment and operation of the network
INAC network

**TDMA based solution using SkyWAN modem**
- Meshed network
- Low bandwidth consumption

**Frame Relay network with Memotec product**
- Reliable product
- Well suited to Aeronautical networks

**An evolutive network:**
- Upgrade to 31 stations in 2008
- RADAR Broadcast
- Integration of AMHS in 2010
Aeronautical VSAT networks in Africa: SADC-2 / NAFISAT / IVSAT

ATNS

Date: 2006 - 2008

Renewal of the VSAT network for SADC and NAFISAT countries as well as ATNS domestic network (IVSAT)

- Turnkey VSAT network including 43 stations in 28 countries for fixed services (SADC and NAFISAT) as well as mobile services (IVSAT)
- Interconnection with AFISNET (ASECNA)
- On demand bandwidth allocation
- Monitoring and control on each site with two centralized centers (Nairobi and Johannesburg)
- Seamless integration with the Radar system, VHF, AFTN, ATN and ATS/DS
Reference – Telecommunication Project

Peruvian VSAT project

CORPAC

Date: 2009 - 2011

Customer objective

– VSAT network for the new RADAR system
– Migration of existing services
– 8 stations across the country

INEO Solutions

– Turnkey solution including studies, VSAT stations and space segment allocation
– Fully hardware-redundant system
– Main link through satellite, backup link through existing REDAP network (terrestrial)
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Satellite access analysis
Incident of ANIK E2 on January 20th 1994

On January 20th, 1994, Telesat Canada’s Anik E2 satellite experienced an attitude control failure due to a solar storm. Anik E2 began tumbling uncontrollably. The satellite was eventually recovered using a unique ground-based determination and control system. Anik E2 resumed service on August 1st, 1994, about six months after the solar flare.

- Satellite was back into business using a innovative technique based on ground loop control (GLACS)
- Enhanced satellite availability improvements
Satellite attitude methods

- **Attitude control is mainly computed inside the satellite**
  - Position sensors for Three-axis regulation
  - Phase comparison techniques to obtain the Round Trip Time (distance estimation)

- **Telecontrol, Tracking and Command (TT&C) link with earth operation center.**
  - Communication link in Payload band (C, Ku or Ka).
  - Backup link in S-band using an on-board low-gain antenna
Satellite obit variations

- Satellite's orbit is never perfect, the latitude and longitude vary with time.
- Centre of Box predicts are used to point ground antennas at the satellites in orbit.

Path of the satellite over a one-week period. Each day, there are two points where the satellite comes closest to the centre of the station keeping box.
3.8m C-Band antenna pattern

3.8m C-band offset-feed antenna. Pattern given at 3.950 GHz.

0.05° variation is minimal: # 0.3 dB (linear approximation)
Incident of ANIK F1 May 10th 2011

“[…] Anik F1 suffered an unanticipated and unforeseeable attitude disturbance which caused a loss of earth lock. […] the attitude disturbance was caused by a high acceleration imparted on the spacecraft (which was beyond the control system to handle), which in turn was caused by a ruptured heat pipe on the south west deployable radiator. […]”

David Wendling
Vice President, Space and Network Engineering TELESAT

- Shows the progress accomplished since 1994: 1 day of service perturbation
- Satellite communication still can have troubles
- Telesat has one of the biggest availability: more than 99.97% (99.989 % in 2004)
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Anticipating the future

→ Satellite technologies & IP features
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  - Satellite access: the TDMA hegemony?
  - The IP convergence
Satellite Access:

the TDMA hegemony?
Point to Point - SCPC

- One carrier per link
- Each carrier only contains information for remote site
- Hubless connections (Point to Point)
- One pair of modem per connection

Well suited for:
- Networks with a high percentage of permanent circuits
- High availability and robustness
- Small meshed networks or large hybrid networks
Point to Multipoint - MCPC

- One carrier per station
- Each carrier contains information for different remote sites

Well suited for:
- Networks with a majority of permanent circuits
- Star/Hybrid topologies (Star with some meshed links)
- High availability and robustness
- Asymmetric traffic
TDMA

One carrier shared by a large number of stations

- Frequency hopping: Multi Carrier
- Time divided in slots.
- Synchronisation stations (one main, one stand by)

- Well suited for:
  - Networks with a high percentage of DAMA circuits
  - Full Mesh topologies with a large number of sites
  - Flexibility
Bandwidth Allocation

Bandwidth can be allocated permanently (PAMA) or on demand (DAMA)

**PAMA Services:**
- Radar
- VHF

- **Low JITTER**
  - No BW request

**DAMA Services**
- AFTN, AMHS
- ATS/DS
- RCMS (VOR, Radar, VHF, etc)
- M&C

- **BW on demand**
  - PAMA on demand for real time (low jitter)
SCPC/MCPC improvements

Three S/MCPC technical improvements have been developed:

- Adaptative modulation
- Carrier in Carrier
- Use of DVB for multicast stream
Adaptative modulation

Clear sky conditions
→ $\text{Eb/N0}$ is higher than expected by the modulator
→ Higher state modulation

Both MODEM exchange information about the current $\text{Eb/N0}$. A specific constructor-dependent algorithm enables a change in the modulation.
Modulation and coding influence
Adaptative modulation is useful for ATC technologies to get a better throughput for data transfer.

Due to rain falls Eb/N0 is progressively reduced. → Lower state modulation
Based on “Adaptive Cancellation”, Carrier-in-Carrier (CnC) allows carriers in a Duplex satellite link to occupy the same transponder space.

Without double talk Carrier-in Carrier

With double talk Carrier-in Carrier

Carrier-in-Carrier is a Registered Trademark of Comtech EF Data
DoubleTalk is a Registered Trademark of Applied Signal Technology, Inc.
DoubleTalk® Carrier-in-Carrier®

Combined with proper Modulation and FEC, Carrier-in-Carrier allows for multi dimensional optimization

• Reducing bandwidth
  > Occupied Bandwidth & Transponder Power
• Reducing earth RF segment
  > BUC/HPA Size and/or Antenna Size
• Increasing throughput
• Increasing link availability
• Or a combination to meet different objectives
DVB-S coding

DVB-S2 in transmission from the hub
– QPSK, 8PSK, 16APSK, 32APSK
– Roll-off: 20%, 25%, 35%
– ACM capable

Classic 8/Q PSK transmission in reception
MCPC/SCPC analysis

**Advantages**

- PAMA oriented connection
- Cheaper RF part on the remote site
  - Well suited for desert area
  - Low upload traffic
- Cheap unit price
- Star topology

- MCPC:
  - Well suited for asymmetric traffic
  - Cheaper hardware (less modulators)

**Drawbacks**

- No bandwidth on demand (FDMA systems exists)
- Higher frequency spectrum consumption
- Bad suited for Hybrid / Meshed topology
- Requires hardware and frequency spectrum for new connections
Network limits

SCPC MODEM are cheaper by 30% to 70% compared to TDMA MODEM, depending on options and features

• SCPC are suitable for network with few inter-site connections (1 to 3 connections).
• When more connections are required MF-TDMA is more effective

> Reduced number of hardware
> Shared bandwidth
TDMA improvements

- Use of turbo-codes: TPC and company-restricted codes (Turbo-φ).
  - Lower Eb/N0 than Viterbi and Reed Solomon codes

- Use of lower Roll-off factors (0.2)
  - Improves MF-TDMA bandwidth shaping

- No need for an expensive station for time synchronization:
  - integrated in the MODEM (master MODEM)

- Improved safety
Roll-off factor optimization

- A better (lower) Roll-off factor enhances the spectral efficiency of the system:

\[ Bw = \text{Symbol\_rate} \times (1 + \text{Roll-off\_factor}) \]

→ Reduces consumed bandwidth

→ Useful in MF-TDMA
Improved safety by authentification

- **TDMA encryption**: unauthorized station cannot enter the network nor decode the data
TDMA analysis

**Advantages**

- Bandwidth on demand
- Tighter frequency spectrum
- Network flexibility:
  - Add station
  - Add circuits / services
- Powerful in meshed network
- Less hardware

**Drawbacks**

- Modem cost
- Big RF part (large carrier)
  - Larger Antenna/HPA
- Same RF in the network
- Sync station (and backup sync station) station required
- TDMA header (SLL)

Satmex6 - Ku
TDMA vs MCPC/SCPC

TDMA is more flexible than MCPC/SCPC, at the expense of RF part.

Both technologies evolve in parallel, TDMA is not newer or better than MCPC/SCPC (both technologies now support Turbo coding), they answer to different needs and topology

→ Strategic and political choice
→ SCPC/MCPC is suited for STAR topology and Autonomous remote sites
The IP convergence
Voice communications

- VCSS **will be** compatible to be connected directly over IP (and ideally, not through a box converting Voice to IP)
- ATS communication **will be** fully compatible with VoIP

**For the Mobile Service**, Frame Relay remains one of the best options:
- Efficient (low overhead)
- Reliable (INEO installed more than 100 stations in Frame Relay)
Frame Relay is a layer 2 protocol, whereas IP is at layer 3

**Advantages**

- Flexibility of configuration
- Mesh structure with automatic routing (static or dynamic)
- Low price (widespread)

**Drawbacks**

- Bandwidth not optimized
- QOS

**ISO level**

<table>
<thead>
<tr>
<th></th>
<th>IP</th>
<th>Frame Relay</th>
</tr>
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<tbody>
<tr>
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<td>3</td>
<td>2</td>
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**Encapsulation**

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<th>IP</th>
<th>Frame Relay</th>
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<tbody>
<tr>
<td>packet</td>
<td></td>
<td>frame</td>
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**Efficiency**

<table>
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<tr>
<th></th>
<th>IP</th>
<th>Frame Relay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
<td>High – 85% for voice</td>
</tr>
</tbody>
</table>

**G729 data rate**

<table>
<thead>
<tr>
<th></th>
<th>IP</th>
<th>Frame Relay</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 kbps</td>
<td></td>
<td>27 kbps</td>
</tr>
<tr>
<td>27 kbps</td>
<td></td>
<td>11 kbps</td>
</tr>
</tbody>
</table>

**Advantages**

- Flexibility of configuration
- Mesh structure with automatic routing (static or dynamic)
- Low price (widespread)

**Drawbacks**

- Bandwidth not optimized
- QOS

- Optimization of space segment
- QOS
- Supports various protocols (async, sync, E&M)

- Hardware cost
- Proprietary of access device type
A declining technology

Frame Relay Access Devices are no longer improved
  → Evolutions and new feature only
  → No major product evolutions

Satellite MODEM are dropping Frame Relay:

  New ND Satcom IDU 1070: Fully IP
  → Problems for spare parts
  → Small market with higher product cost
Data transfer tendencies

Most of Data services are turning to IP

- **AMHS** over IP instead of AFTN
- **RADAR** service over IP instead of serial

**RADAR** service requires fixed delay to compute country-wide data

→ Jitter is critical

→ IP is bad suited to synchronism and jitter-free application

**SOLUTION:**

Huge bandwidth (Optical Fiber)

Use of smart concepts: QOS/TOS IP
TCP-Acceleration

TCP-A:

-Selective acknowledgement
  > Receiver informs the transmitter which packets must be re-sent

-Multiple packet emission: large « Window » transmission
  > Transmission of multiple packets without Ack
  > Reduced number of Ack

-Improved file transfer through satellite
  > Lower delay impact on file transfers
  > Higher data throughput
Thank you for your attention
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