AGENDA

• Original ARTES project (2004-2006) in which we demonstrated first implementation of high speed internet over satellite on a high speed train (Renfe), and then a commercial trial (Thalys);

• followed by a review of the developments we have undertaken since then focusing on our implementation on the Italian second railway operator NTV;

• and lastly a summary of the challenges ahead to improve performance (VPNs, improved modems), bandwidth and antennas
## Original ARTES

### Broadband to Trains Project

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Month</th>
<th>Original Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kick Off</td>
<td>9 Feb 2004</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BDR</td>
<td>31 Mar 2004</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>PSV</td>
<td>4 Nov 2004</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>SDA</td>
<td>18 Apr 2005</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>FR</td>
<td>6 Feb 2006</td>
<td>24</td>
<td>15</td>
</tr>
</tbody>
</table>
Technical Trials in Spain - 2004

High Speed Internet for High Speed Trains
21Net + Renfe AVE
Pilot Trials - June
25,000 Volt Cable!
World Firsts

We believe that 21Net / Renfe’s pilot trials represent:

- World’s first demonstration of high speed internet access from a high speed train
- World’s first demonstration of bi-directional Ku band satellite communication to and from a train
  - Receive Data Rate: 4 mbps
  - Transmit Date Rate: 2 mbps
Commercial Pilot on Thalys - 2005

High Speed Internet for High Speed Trains
21Net + Thalys Commercial Service
“Everyone is eager to begin accessing the Internet onboard trains. 21Net’s technology is certainly making this become a reality.”

European Space Agency 21 April 2005

Video produced by European Space Agency
System Architecture
21Net is using Hispasat 1D satellite, that has very good coverage for Spain and Central Europe - > 52dB (green contour). Satellite Operator Approval already granted. For Renfe tests, we used 4mbps receive, 2mbps transmit; For Thalys Pilot, we used 2mbps receive, 0.5mbps transmit.
Satellite Ground Station
Arganda, Spain
Satellite Communication System

- Used DVBS for forward link
- SCPC for return link
- Vipersat Satellite Modems on Train and in Hub (picture)
Satellite Antenna

- Modified version of 80cm diameter maritime antenna

- Modifications:
  - Lower to fit within height profile (72cm)
  - Stronger
  - Modified Acquisition and Tracking Software
Specially designed for train environment

Much stronger than maritime radome
Commercial Developments since 2004-2006
Broadband to Trains ARTES project
21Net Customer: Thalys (Amsterdam, Brussels, Paris, Cologne)

- 26 High Speed TGV trains
- 8 million passenger journeys per year
- “ThalysNet” Service started May 2008: almost 3 million users
- Internet on board very popular: Free in Business (up to 40% usage) and EconFlex(12%)
Indian Rail

- The world’s Largest Railway company - 1.6 million employees, 8,000 trains!
- Successful trial in January 2009 on Mumbai - Ahmedabad Shatabdi Express
- First contract for Internet on Board 3 Rajdhani trains between Delhi and Calcutta
First WiFi service: Delhi - Kolkata Rajdhani 7/3/2013
Indian Railways

- 8,000 Trains
- 8 million passenger journeys per year \text{ DAY !}
- Want to give free Wi-Fi on top trains (Rajdhani, Shatabdi)
- Budget approved for equipping 50 more trains in 2013 budget
The Main Rack
• 25 High Speed Alstom AGV trains
• Europe’s most modern train: Telematics a key feature
• > 10 million passenger journeys per year
• “.italo live” Service started May 2012
Working with NTV to create .italo live
• Cinema Car and At Seat Audio
Cinema car

- Full length movies, and trailers, in special Cinema Car
- 8 overhead high resolution screens
- Every seat equipped with headphone jack, volume and channel selector
- Supports multiple languages
Multimedia Portal

- Touchscreens & Rich Content Portal
- Live TV
- Video on Demand
- Newspapers, Books, News, Weather, Travel
IPTV

- Sky TG24 24 Hour news channel
- Can add additional channels in the future
IPTV available on all devices:

- Laptops
- Tablets
- Smartphones
• Dynamic Multi / Unicast technology over shared satellite link means IPTV plays continuously as train travels at 300 km/hr despite obstructions, bridges and tunnels*
  • *except the very long tunnel between Florence and Bologna

• Very popular on board
Satellite Antenna integrated into roof
• Rooftop section designed and built by 21Net tightly integrated into design of Alstom AGV train
Another key technology: Gigabit Backbone
NTV is a Much More Complex system than Thalys
Lessons Learnt from launch issues

• Time spent in detailed system design, quality assurance and stress testing always time well spent

• Expect some teething troubles: Overcome them by -
  • Measuring real metrics of the passenger experience
  • Continuous rapid improvement
The 21Net services on both NTV and Thalys are very popular with up to 4,000 users a day on each service.
Develop:

New technologies to increase bandwidth by an order of magnitude from single digit mbps to 10s of mbps over BOTH

Sat (Ka) and
Cell (LTE)

and Combo business models with useful contributions from

train operators (eg for free services in first class),
telcos for WiFi or 3G/4G, IPTV,
advertising, content providers, promotions
### Usage Statistics

<table>
<thead>
<tr>
<th></th>
<th>Thalys</th>
<th>NTV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Passengers / Year</strong></td>
<td>7m</td>
<td>8m (est current run rate)</td>
</tr>
<tr>
<td><strong>Trains in Service (Dec 12)</strong></td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td><strong>Capacity per train</strong></td>
<td>350</td>
<td>440</td>
</tr>
<tr>
<td><strong>Business Model</strong></td>
<td>Free in CF1, and part of CF2 (“CF2 Flex” fare)</td>
<td>Free throughout the train</td>
</tr>
<tr>
<td><strong>Max Data Rate per train in service (mbps)</strong></td>
<td>4 down / 0.5 up</td>
<td>8 down / 0.5 up</td>
</tr>
<tr>
<td><strong>Total Data Rate for fleet over Satellite link (mbps)</strong></td>
<td>11.3 down / 2.8 up</td>
<td>16 down / 3 up (includes 3.6 mbps of IPTV on downlink)</td>
</tr>
</tbody>
</table>
Usage statistics (NTV)

On a typical busy day, we see a total of 4,000 users with a peak of 1,400 simultaneous connections across 12 trains running at the same time.

<table>
<thead>
<tr>
<th>NTV network</th>
<th>Down</th>
<th>Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Bytes transmitted in one day</td>
<td>121 GBytes</td>
<td>15 GBytes</td>
</tr>
<tr>
<td>Average Bytes per User session</td>
<td>30 MBytes</td>
<td>3.7 MBytes</td>
</tr>
<tr>
<td>Av. data rate per user session (= 100 minutes)</td>
<td>40 kbps</td>
<td>5 kbps</td>
</tr>
<tr>
<td>Typical Total Data Rate from datacentre (16 hour day)</td>
<td>20 mbps</td>
<td>2.5 mbps</td>
</tr>
<tr>
<td>Of which, over satellite peak (excluding IPTV)</td>
<td>12 mbps</td>
<td>3 mbps</td>
</tr>
<tr>
<td>Satellite bandwidth average (excluding IPTV)</td>
<td>9 mbps</td>
<td>2 mbps</td>
</tr>
</tbody>
</table>
On NTV, downlink data rate is 10 - 16 mbps during the active time of day, of which 3.6 mbps is IPTV.

Uplink data rate is 2 - 3 mbps.

Data applies to current fleet of 21 trains, of which 12 maximum active at same time.
In 21Net’s system, data connectivity to moving trains is provided by Cellular networks when available, and by Satellite when not.

Typically data capable cellular connectivity (UMTS or better) is now available within cities and suburban areas, though usable bandwidth depends on total usage of each base station. Typical data rates of 3 mbps with 3G networks. Higher rates can be achieved with HSPDA+, and are expected with 4G / LTE, but these network technologies are still rather scarce.

In most large European countries, there is little or no 3G in the countryside. Consequently the coverage along high speed train routes can be ~ 50 %
Network deployment follows population density.
Economics of satellite connectivity

› The cost of a Gigabyte of data to a moving train is significantly higher over satellite than over cellular

› However the advantage of providing 95+% Internet availability over a whole journey rather than 50 - 75%, justifies the cost provided that the total cost to the train operator is commensurate to the passenger benefit.

› This cost is essentially fixed at a modest amount per passenger journey although users’ appetite for mobile data is increasing at a significant rate: 60% pa according to Cisco (http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360.pdf)

› Therefore 21Net is looking to significantly increase its satellite (and cellular) connectivity bandwidth over the next few years without a major increase in the total cost.

› This ought to be achievable with a migration from Ku to Ka-band or a realignment of Ku-band pricing in line with Ka-band more competitive prices
To achieve sensible opex for satellite connectivity requires a high gain antenna (eg G/T = 17 dB/K), dynamic bandwidth assignment and state of the art coding schemes (DVB-S2, ACM) to give high spectral efficiency.

We expect to move from single digit mbps to double digit mbps data rates over satellite, and also

over cellular using LTE when available, + multiple SIMs and optimised antennas to get maximum performance for 3G networks

and by implementing a second generation Mobile Access Router (“MAR2”) that aggregates (viz combines) connectivity from satellite and cellular links
Challenges

• VPNs - Sometimes problems with VPNs over satellite links
• Improved modems and spectral efficiency
• Bandwidth (4 -> 40 mbps; Ku -> Ka)
• Antennas
Modem Developments for COTM

2.3 ACM in the Return

Adaptive TDMA in Action

Dynamic carriers in Return using iDirect

QPSK 3/4  QPSK 3/4  QPSK 3/4  QPSK 3/4  QPSK 1/2  QPSK 1/2

ClearSky Widespread Fade

Hub Side Fade

- Frequency Hopping based on remote’s link condition
- IRG MODCOD changes based on wider fade condition
• For satellite connectivity, 21Net is developing a Ka version of its 30RR antenna that could be retrofitted to existing trains (eg NTV, Thalys)
• 21Net is working with sister company, Phasor Solutions, on a new, completely flat, electronically steered phased array antenna which will be especially important for trains without much head-room (e.g., UK trains, SNCF Duplex). This should be introduced in 2014 / 2015.
Leading the way in Broadband and Multimedia on board Trains

Thank You

www.21net.com

henry@21net.com