Some topics in satellite networking

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advanced networks colloquium series
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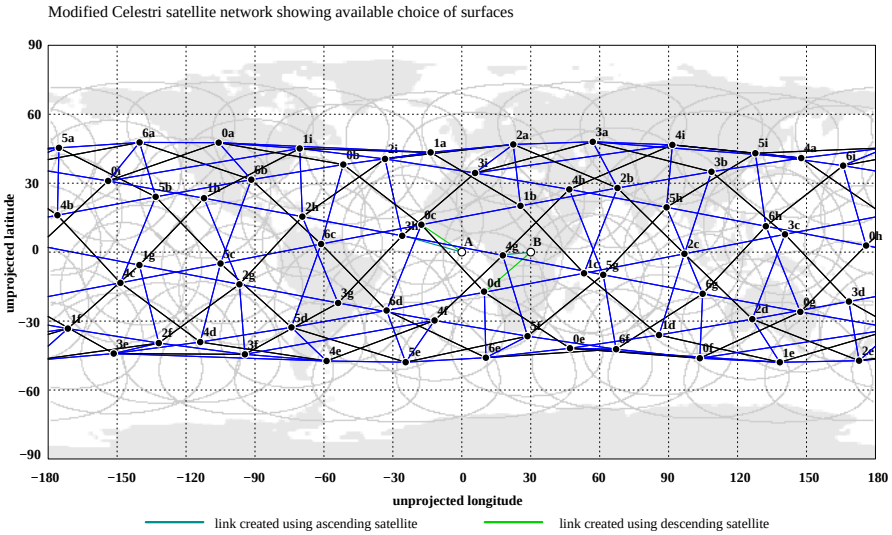
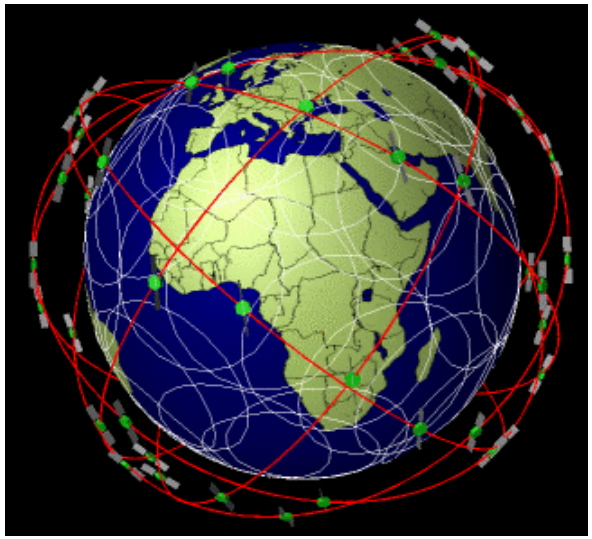
Quick summary of this talk

- my personal perspective
  - where I’m coming from, with previous research.
  - where the satellite industry went in reality instead.
- real areas in satellite networking to watch
  - IP multicast.
  - DVB over satellite.
  - performance enhancement/link utilisation.
- working for Cisco
  - after my years working on IOS development...
  - what is Cisco’s Global Defense & Space Group?

Lloyd's previous research

- Looked at (IP) networking over satellite constellations
- ground-based vs space-based; focused on space-based (with intersatellite links). Used *ns* heavily.
- focused on orbital geometry, movement, and delay.
- wireless networking with handover problems.





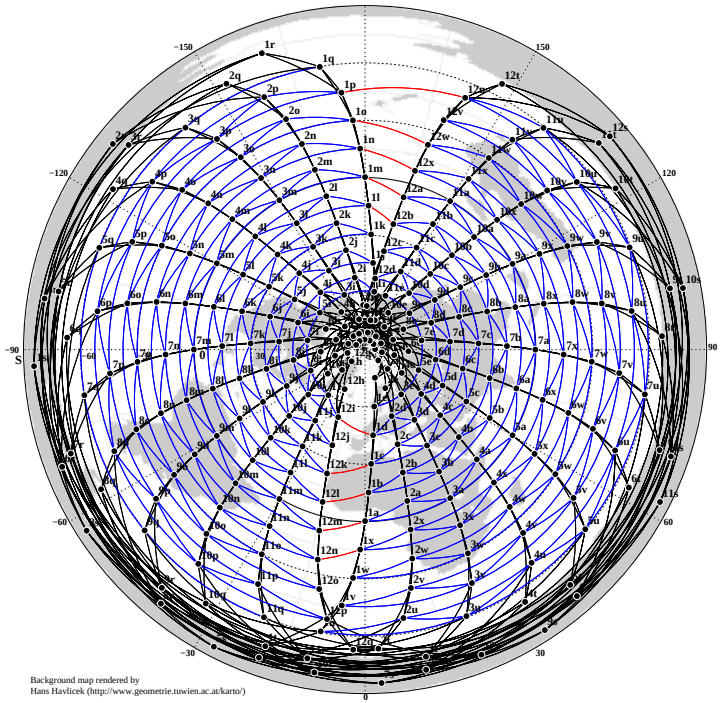
two views of Motorola's *Celestri* proposal (*ns*, *SaVi*)

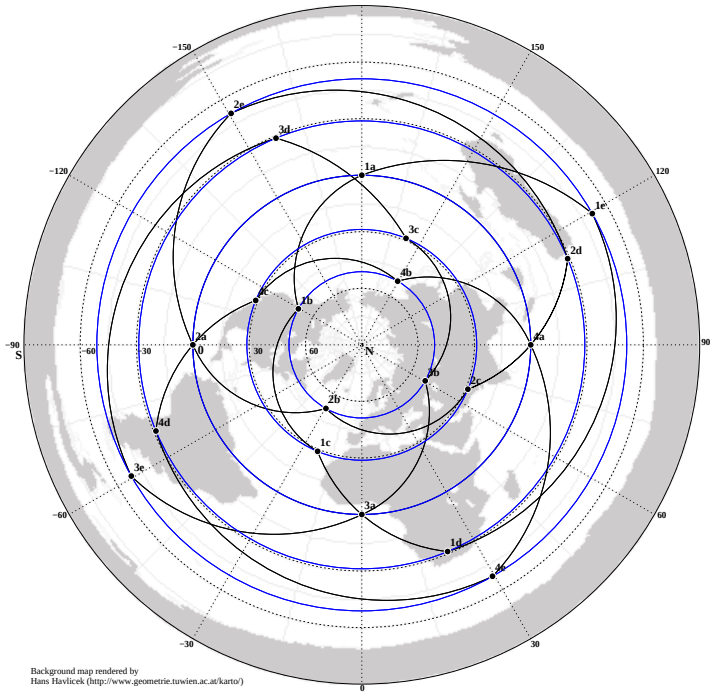
all uncredited images: Lloyd's PhD work (online at Lloyd's webpages)

Ground vs space-based constellation networks

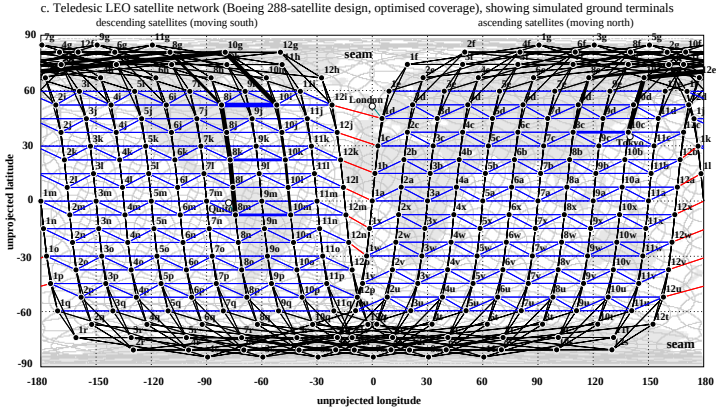
Without intersatellite links	*With* intersatellite links (ISLs)
Satellites *are* just ‘last hop’. Users must be in same satellite footprint as gateway station for connectivity.	Satellites *aren’t* just ‘last hop’. Users don’t need to be in same satellite footprint as gateway station for connectivity.
Coverage over remote areas (oceans) where there is no local infrastructure not possible.	Coverage over remote areas (oceans) where there is no local infrastructure possible.
Physical delay within space segment highly predictable and small; depends upon terminal-satellite-gateway hops during passes; likely to be symmetrical.	Physical delay within space segment highly variable but deterministic; depends on where terminals and gateways are, path between them. May not be symmetrical.
Delay in ground segment **unknown**. Resulting total delay **unknown**.	Can neglect ground segment. **Can model space segment, find delay.**
Onboard processing and switching are *optional*. No onboard routing.	Onboard processing, switching, routing are *necessary*. It really is a network.
example constellations: *Globalstar, ICO, Skybridge*	example constellations: *Iridium, Teledesic, Spaceway*

Constellation geometry - star *vs* rosette (LEO/MEO ISL designs)

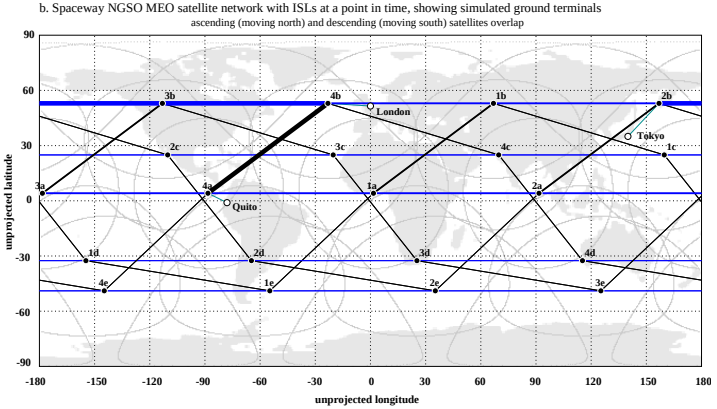




Teledesic (Boeing design - 288 active satellites)

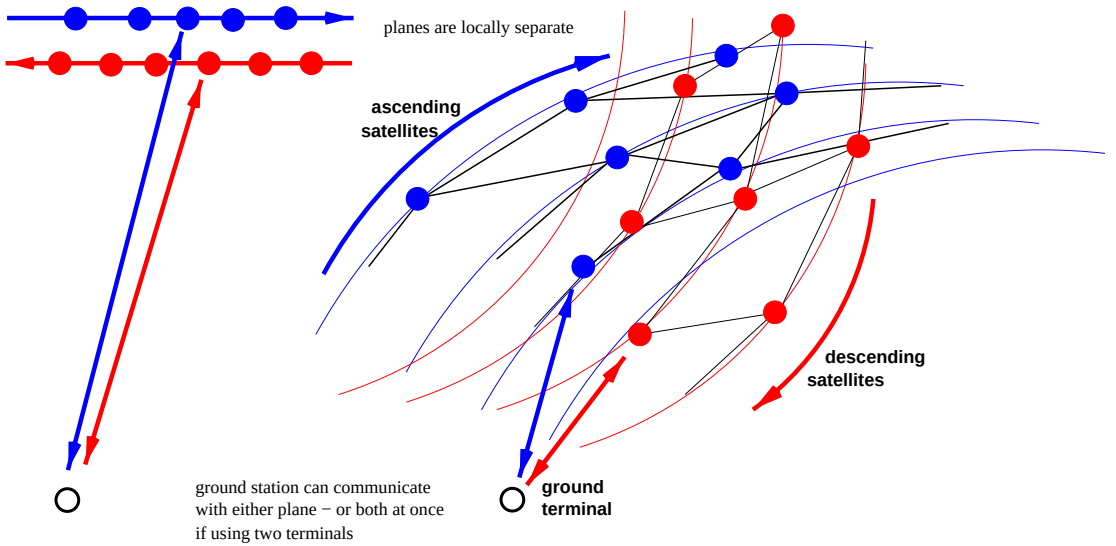


Hughes *Spaceway NGSO* (20 active satellites)

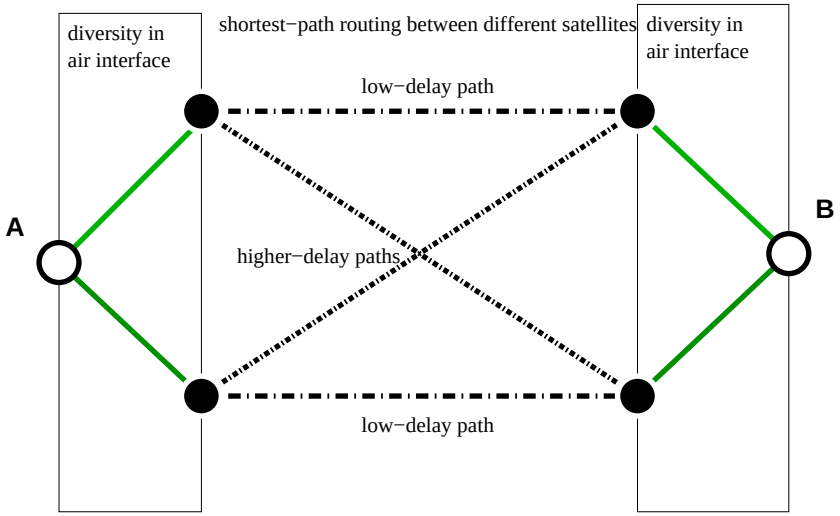


Handover in rosettes with intersatellite links (ISLs)

Both *ascending* and descending *satellites* mean two parts of the ISL mesh can be seen overhead; two network *surfaces*. By *multihoming* ground terminals we increase reliability, and can also introduce two sets of path delays…



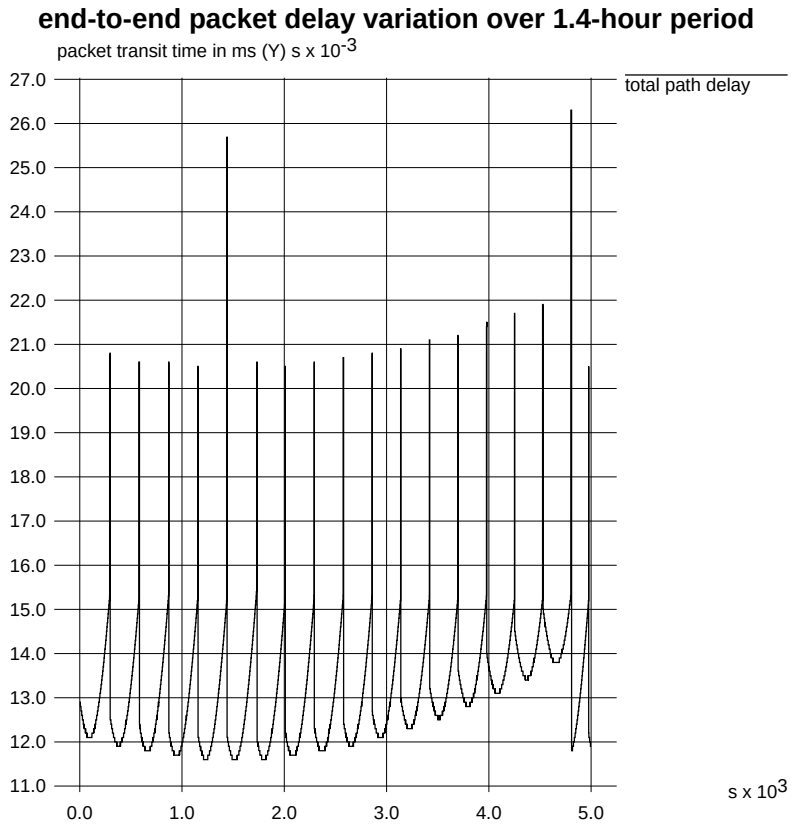
Current rosettes (e.g. *Globalstar*) just use this for diversity in the air interface.

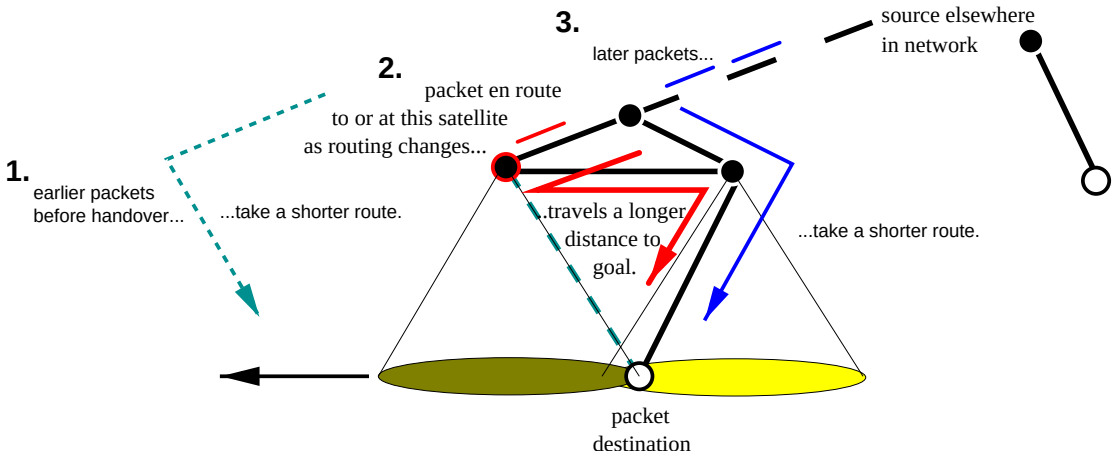


Handover and packets in flight

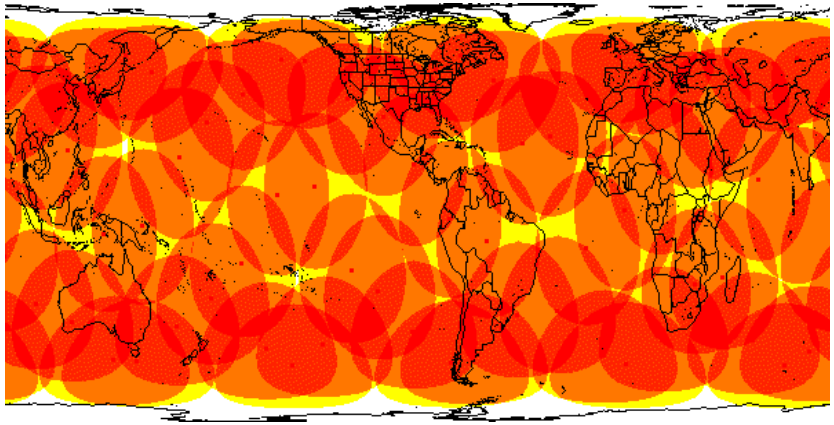
Star seam (flipping between surfaces) is worst, but there are transient spikes in path delay for packets in flight whenever your terminal undergoes a handover.

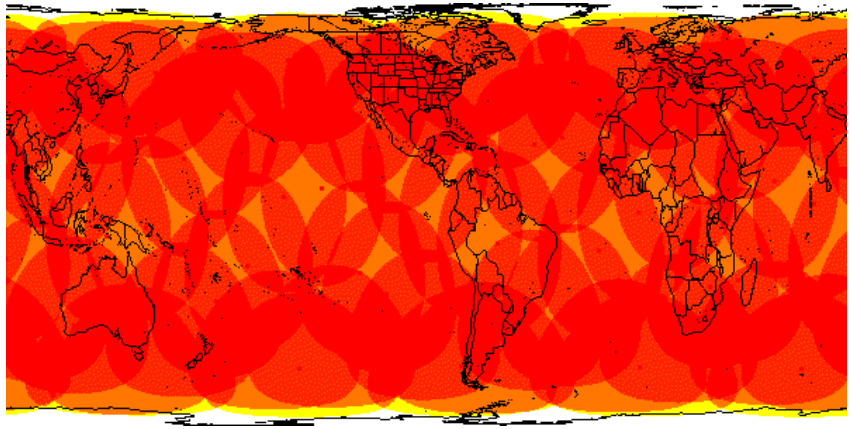
This has implications for moving network state (for multicast?) between satellites.
If you don't want to disrupt high-rate traffic, you want small spikes of no more than 1 ISL hop.
Avoid flipping surfaces.





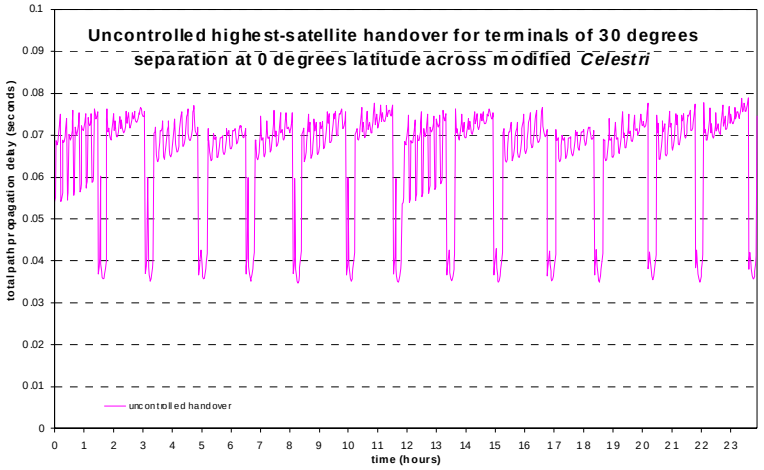
Value of controlled handover for multihomed terminals

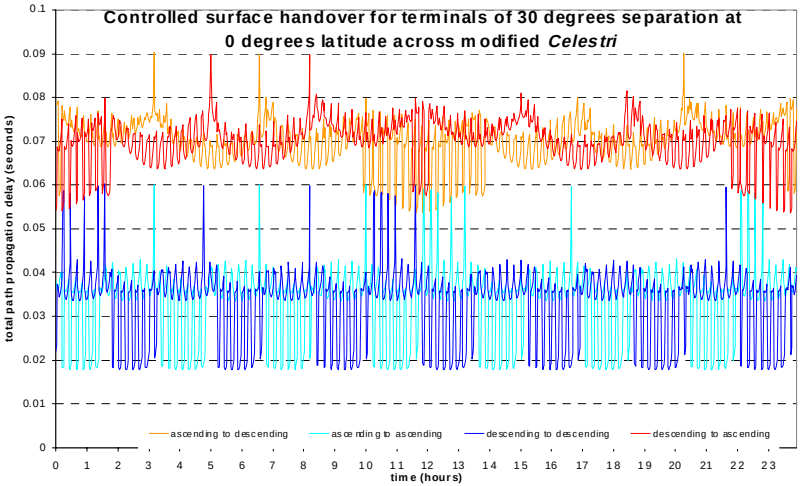




LEO *Celestri* coverage (single in parts – multihoming limited)

Modifying for double surface coverage (lower mask elevation angle by 6º)





Single-homed terminals pick the highest visible satellite and flip between surfaces

Multi-homed terminals stick to a surface and give two sets of delay classes

Multicast trees in the ISL mesh

Looked at core-based trees in LEO/MEO constellations.

Bad analogy - imagine ‘virtual spider’ holding the Earth...

Body is core (sum of vectors); feet touch terminals.

satellites flow through, inherit part of the spider state, leave.

duplication done in mesh; save precious Earth-space interface.

Not much like GEO broadcast!

image: huntsman spider and egg pouch, http://www.eryptick.net/

Meanwhile, in the *real* world... handheld satellite phones arrive

Big-LEO voice constellations launched!

- ***Iridium***
  - service launch 1998, 80ish satellites now up
  - bankruptcy protection 1999
- ***Globalstar***
  - service launch 1999, 52 satellites up
  - bankruptcy protection 2002
- ***ICO* (Inmarsat MEO voice)**
  - bankruptcy protection 1999 *before* any launches
  - taken over by McCaw (Nextel, **Teledesic**) 2000
  - only one satellite up, no service yet
- ***Orbcomm* (messaging, little LEO)**
  - lots up, but bankruptcy protection 2000
- **and whatever happened to *Teledesic*?**
  - scaled back – 840 to 288 to 30 MEO active satellites
  - Ka-band frequency landgrab; nothing up.

Iridium, *Globalstar* handsets not to scale

images: http://www.iridium.com http://www.globalstar.com/

So why weren’t satphones an immediate success?

World now has **GSM roaming**

– well, apart from much of US (and S. Korea/Japan).

World doesn’t need satphones – well, business travellers don’t.

Satphones back to niche applications – mining, yachting, military.

image: Nokia
http://www.nokia.com/

And now, the present.

- Constellations still used for navigation/geodesy (*GPS*, *Glonass*, upcoming European *Galileo*).
- LEO useful for remote sensing applications
  - use increasing (e.g. Surrey's DMC)
- GEO satphones have now arrived (*Thuraya*)
- GEO broadcast still doing just fine, thanks.

  What's happening there?

  Television (increasingly digital, encrypted settop boxes)

  Traditional VSATs / Inmarsat etc. – this is changing

  Still some voice, data trunk networking.

Approaches to IP networking across GEO

- World has gone IP networking, but satellite market very conservative; Inmarsat et al. based on ISDN/SDH. (Okay, ignoring *DirecPC/Spaceway* here)
- World (well, Europe, anyway) has gone towards MPEG DVB decoder hardware – cheap, in set-top boxes everywhere.
- How to do IP over MPEG?
  - MPEG MPE (multi-protocol encapsulation)
  - not efficient, MPEG transport stream uses 188-byte packets with a lot of header overhead.
  - improve encap efficiency
    - Gorry Fairhurst attempted IETF WG with BOFs.
- In satellites, spectrum is scarce and saleable.
- Link efficiency *really matters*.

IP multicast

- Did I say link efficiency really *matters*?
- Multicast goes to more than one recipient. More than one subscriber – resell the same packet twice!
- Vendors *like* multicast!

- How to do IP multicast well? Map to lower layers?
- ETSI Broadband Satellite Multimedia group/DVB-RCS

- Lots of non-standard link issues. How to do joins and leaves efficiently? IGMP snooping onboard?

- How to support IP QoS from terrestrial network all the way through the link? QoS needs tight coupling.

Onboard processing (OBP)

- Satellites slowly climbing up the networking stack; very conservative deployment.
- Space is a harsh environment for processors (power/radiation and single-event upsets/cooling)
- Splits and separates uplink and downlink, allowing separation of errors/recovery (DSP/decode to baseband?)
- Do packet-switching onboard? (Useful for ISLs.) Why else? What are benefits? (local IGMP snooping for spotbeams? ARP speedup? Reliable multicast resends? Lawful intercept, even?).

TCP performance enhancement

- Satellite GEO market big on TCP spoofing – breaking end2end, ignoring congestion/removing slow start across satellite link to get performance boost across GEO delay bottleneck. Custom accelerator boxes.

- World is going IPSec encrypted in VPNs, where you can't spoof or split TCP, because you can't *see* TCP.

- TCP endpoints will get smarter/more paranoid (Stefan Savage's DoS attack papers, Mark Allman's drafts)

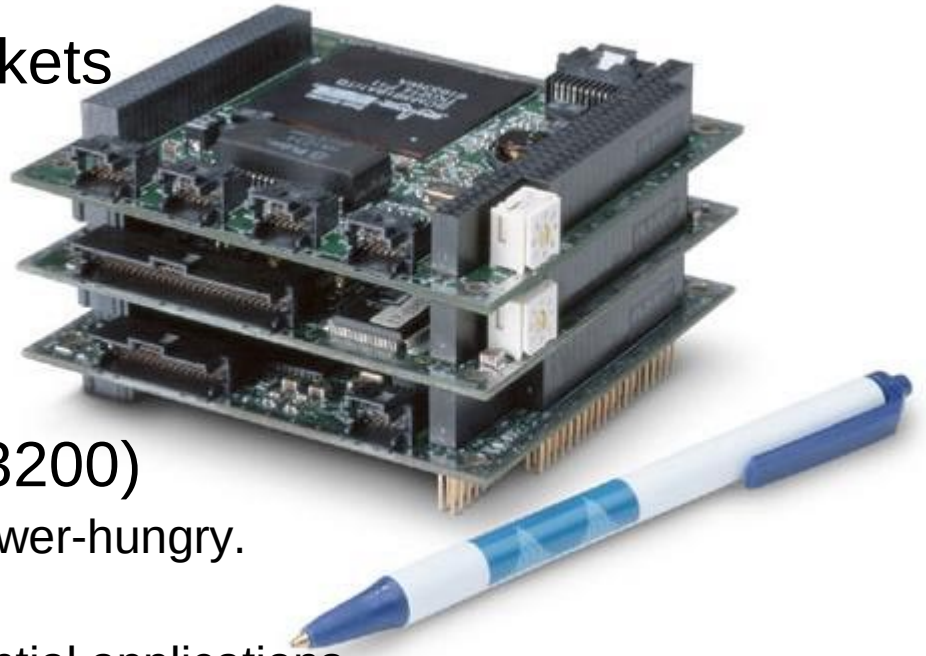
- How to improve GEO performance? Weaken security by how much, exactly? Improve handling of QoS semantics through layers? Delayering?

Interplanetary Internet group

- Vint Cerf and cohorts' Internet Society research group.
- 'Bundles' – looking to layer over IP, as IP layered over everything else. Smart, well-described data packages.
- -01 internet-draft describing architecture.
- Some example software due out Real Soon Now.
- Focus expanded to Delay-Tolerant Networking; GEO satellite was worst-case delay in early days (SATNET), but IP was designed to cope with it; solar system delays much bigger.

At Cisco – looking at space/mobility applications

- Global Defense & Space Group now a year old
- Looking at new (vertical) markets
  - where are they going?
  - how will they leverage IP?
  - what new abilities does IP bring?

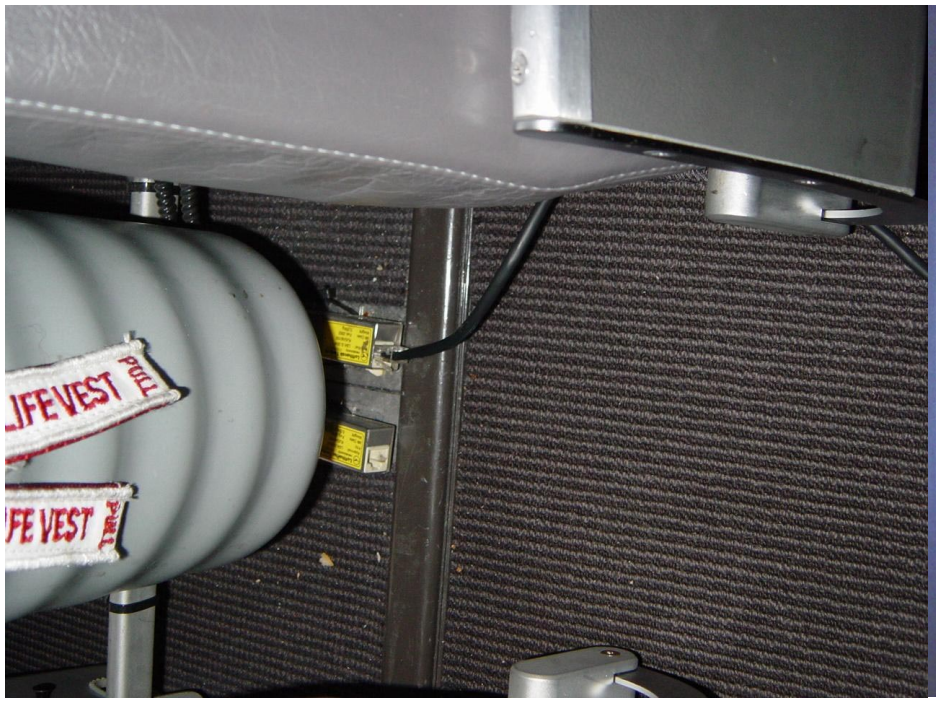


- Mobile Access Router (MAR3200)
  - small, not in a 19” rack, not that power-hungry.
  - PC104 form factor. Runs IOS.
  - figuring out and learning from potential applications.
- Inflight connectivity - Lufthansa trialling MAR
  - Boeing’s Connexion, also being trialled by British Airways.
  - where else?

image: Cisco Systems
http://www.cisco.com/

Connexion

- Mobile access router onboard Lufthansa Boeings; cabled seats for first class, economy shares 802.11b wireless.
- Electronically steerable phased-array antennas
- Ku/L-band Inmarsat uplink; Ku-band downlink.



competitors: Tenzing – sporadic access for send/receive email on Cathay/Virgin
European research project in this area: http://www.wirelesscabin.com/
images: courtesy Dr Klaus-Peter Dörpelkus, Cisco Systems

Questions?

thankyou