Convergence of Terrestrial and Space Communications - Where are we?

An user's perspective in space science

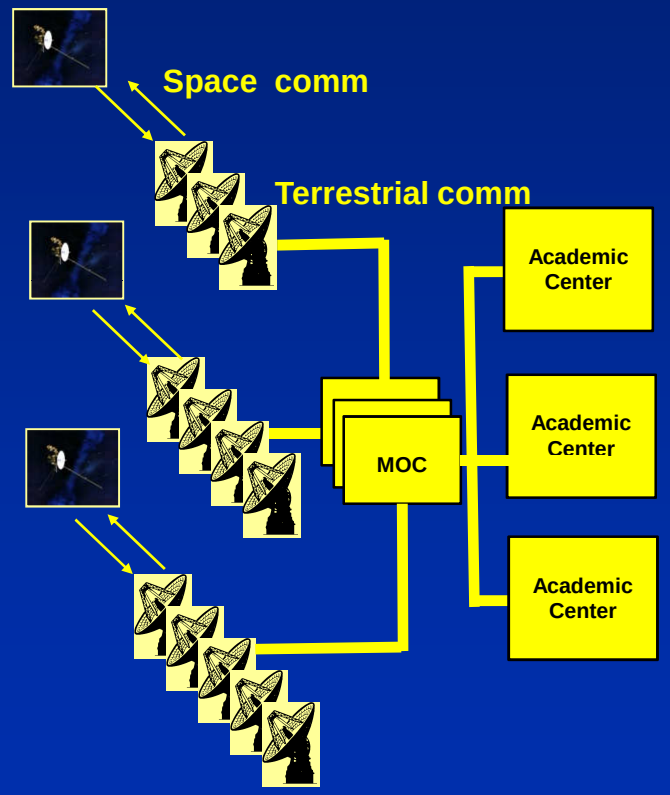
Tim Pham

Jet Propulsion Laboratory

California Institute of Technology

Synergy of Two Systems within NASA DSN

- Space communications system
  - Connect Spacecraft ⟷ Tracking Stations
  - Enable scientific data collection
- Terrestrial communications system
  - Connect Tracking Stations ⟷ Mission operations centers ⟷ Academic Research Institutions
    - Wide area network over 10,000 km
  - Distribute science data to investigators; enable mission operations
- Discussion focused on cost trend in terrestrial system
  - Important in funding constraint environment



Cost Drivers

- Cost in terrestrial's wide area network dictated by desires of
  - High reliability
  - Sufficient bandwidth/low latency
  - Good security
- Cost also driven by remote location of tracking stations
  - Single user
  - Limited choice of providers

Reliability Considerations

- Driven by a need to maintain constant/immediate contact with spacecraft
  - For critical events, e.g., planetary encounter or landing
- Requiring
  - Equipment redundancy
  - Routing diversity
  - Minimal or no single point of failure

  >> Low MTTRS and high MTBF

Bandwidth & Latency Considerations

- Bandwidth need
  - Increased over time
    - Near-Earth missions, 10-100 Mbps
    - Deep space missions, 1 - 10 Mbps
  - Aggregated over all supported missions
  - Sufficient capacity needed to clear delivery before next tracking pass
- Low latency need
  - Support routine mission operation timeline
    - Design new spacecraft sequence of events from received telemetry
  - Supporting mission critical events
    - Enable quick response to problems at critical time
    - Enhance public outreach/engagement
- Terrestrial systems sufficiently meet space operation need
  - Constrained mainly by high cost

Security Considerations

- Drivers
  - Commitment to protect mission data integrity
  - Bad publicity with break-ins
- Approach
  - Isolate network as much as possible via vendor’s dedicated fibers

Trend in Cost of Terrestrial Services

- Cost has dropped significantly (~4x) over past decade
  - Achieved through technical advances in terrestrial networks
    - More automation
    - Consolidated operations
    - Market competition in commercial sectors
  - Still higher than equivalent residential fee (~10x)
    - due to dedicated lines for desired service attributes
- More possible cost reduction with leverage on internet infrastructure
  - From nearby major POP
  - Last-mile connection cost likely remains
    - Residual higher cost expected (compared to residential fee), but less than current ratio

Spatial terrestrial convergence

Claus Popp Larsen
Acreo

Convergence, Panel discussion
ICDT 2012

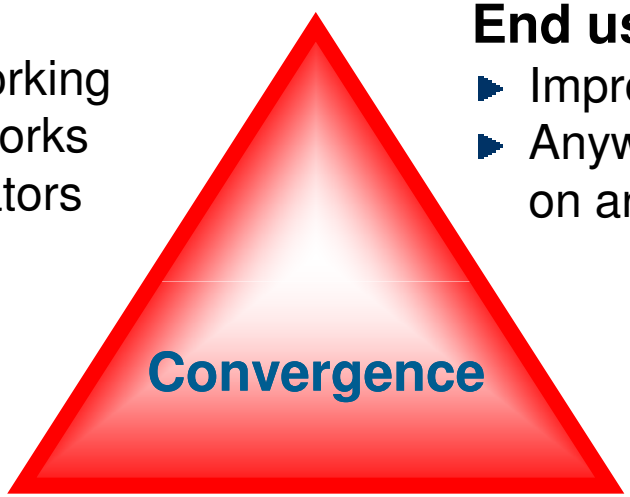
Experiences from convergence workshop

- The term ”fixed-mobile convergence” (FMC) peaked around 2007/2008
- Workshop at ECOC ’2008 in Brussels on convergence tried to sort it out. Presence from:
  - Broadband and optical communications – fibre backhaul
  - Mobile networks – seamless services
  - IT-industry - integration
- Experience: Nobody knew exactly what the others were talking about
- Conclusion: First step in ”convergence” is to bring people together from the segments about to be converged

Different actors, different perspectives

System vendor
- Technology interworking
- More efficient networks
- Attractive for operators

End user
- Improve today's user experience
- Anywhere, anytime, any terminal, on any type of network

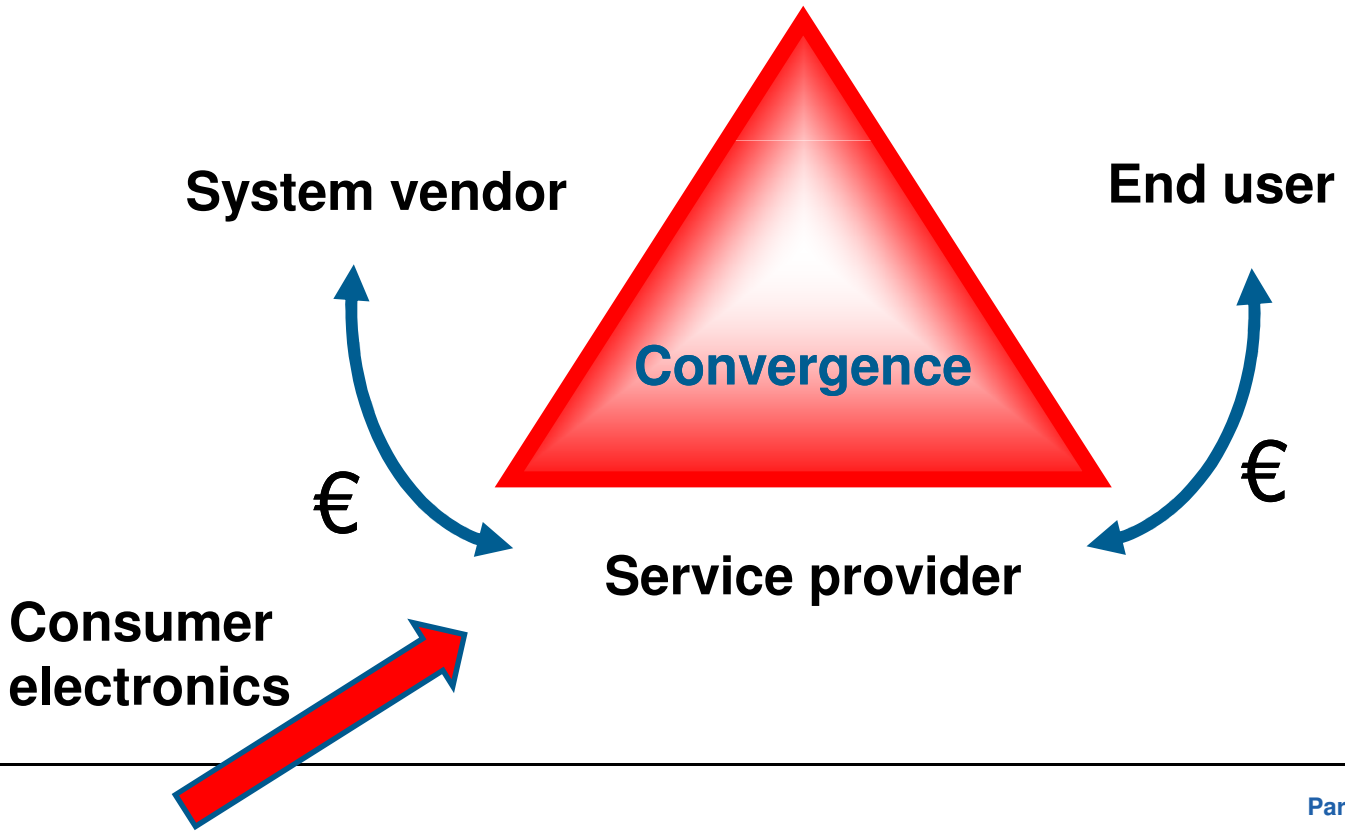


Service provider
- Business models
- Simpler operations
- Customer loyalty

New business models, changed user behaviour

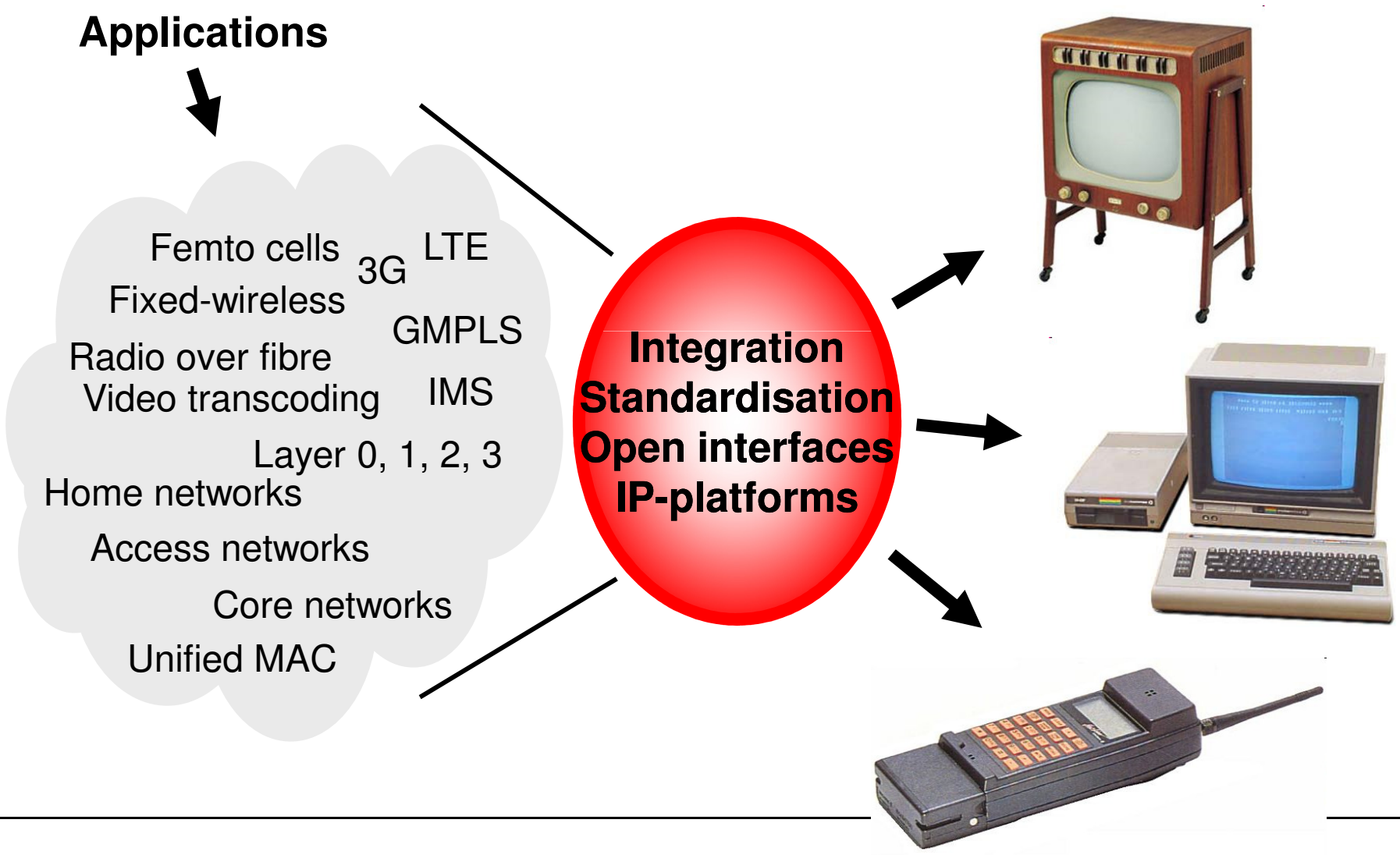
Game rules are dynamic

- Competition gets increasingly fierce
- Old players shift roles
- ”New” players enter the market all the time



Technology perspective

- convergence = integration?



Where are we today?

It’s about understanding eachother, and it’s about meeting end user needs

NEXCOMM 2012

PANEL for ICDT / SPACOMM / CTRQ / PESARO

Terrestrial and Spatial Convergence of Communications: Were Are We?

Convergence in the perspective of Future Internet: architecture, content, Publish/Subscribe models, DTN aspects

Eugen Borcoci,
University Politehnica Bucharest
Eugen.Borcoci@elcom.pub.ro

Convergence in the perspective of Future Internet

- **Future Internet**
  - FI – global technology having impact on all aspects of society life
  - Major efforts to redefine the FI – to solve the current limitations
    - ossification- w.r.t defining and adding new functionalities
      - IP – is still the thin waist of the Internet ?
    - not designed for a global scale
    - orientation to E2E hosts communications (address/location based routing and forwarding) and not on information/content
    - management complexity and overhead
    - adaptability, flexibility, security, etc.

    - **classical architecture and protocols - not appropriate for special environments (e.g. space communications)**
      - **Efforts : DTN technologies, Publish/subscribe models of communication, ..**

    - mobility aspects: terminals, services, users, networks

- *Acknowledgment: this talk will shortly present some ideas compiled from several public available sources, indicated in the Reference list.*

Convergence in the perspective of Future Internet

- **Future Internet**
  - **How to achieve it**
    - Clean-slate, Evolutionary, “mid-way” approaches?
  - **Entities involved:** Research groups, Academia, Industry Standardization organizations Governments, Users
    - A lot of FI –oriented initiatives
  - **Terrestrial– space communications convergence** – naturally included in the FI objectives- still open issue for research
  - **Optimistic reasons for convergence:**
    - Some new FI paradigms – seem to be appropriate also for Space communications
      - information/content orientation
      - decoupling information object name w.r.t its location
      - Publish/subscribe – asynchronous communication model
      - ….

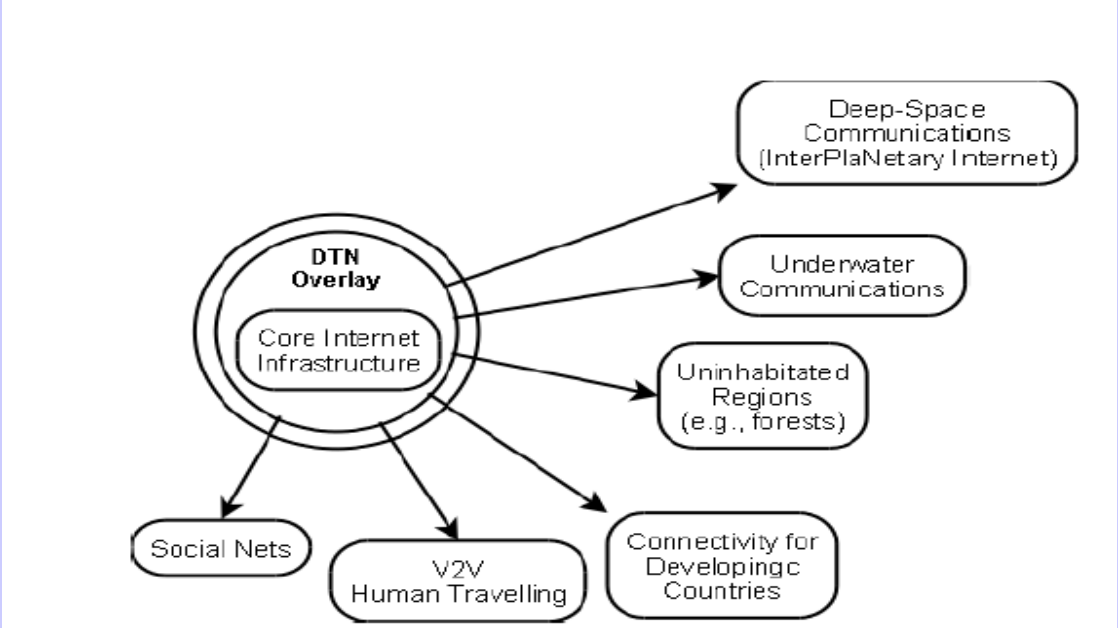
Convergence in the perspective of Future Internet

- **Future Internet- major trends**
  - (ICN) Information Centric Networking,
  - (CON) Content Oriented Networking
  - (CCN) Content Centric Networking ..
    - Partially equivalent overlapping names
    - Many groups involved in research projects, studies, experimentations, development, ..
  - **Major challenges:**
    - Architecture (layers definitions, layer coupling, thin waist, security models, in-network caching, non-layered architectures, DTN-capabilities, synchronous/asynchronous communication models…)
    - Focus on content/information object entity as a main primitive
    - Scalability, backward compatibility, flexibility, availability, levels of service guarantees..
    - ….

Convergence in the perspective of Future Internet

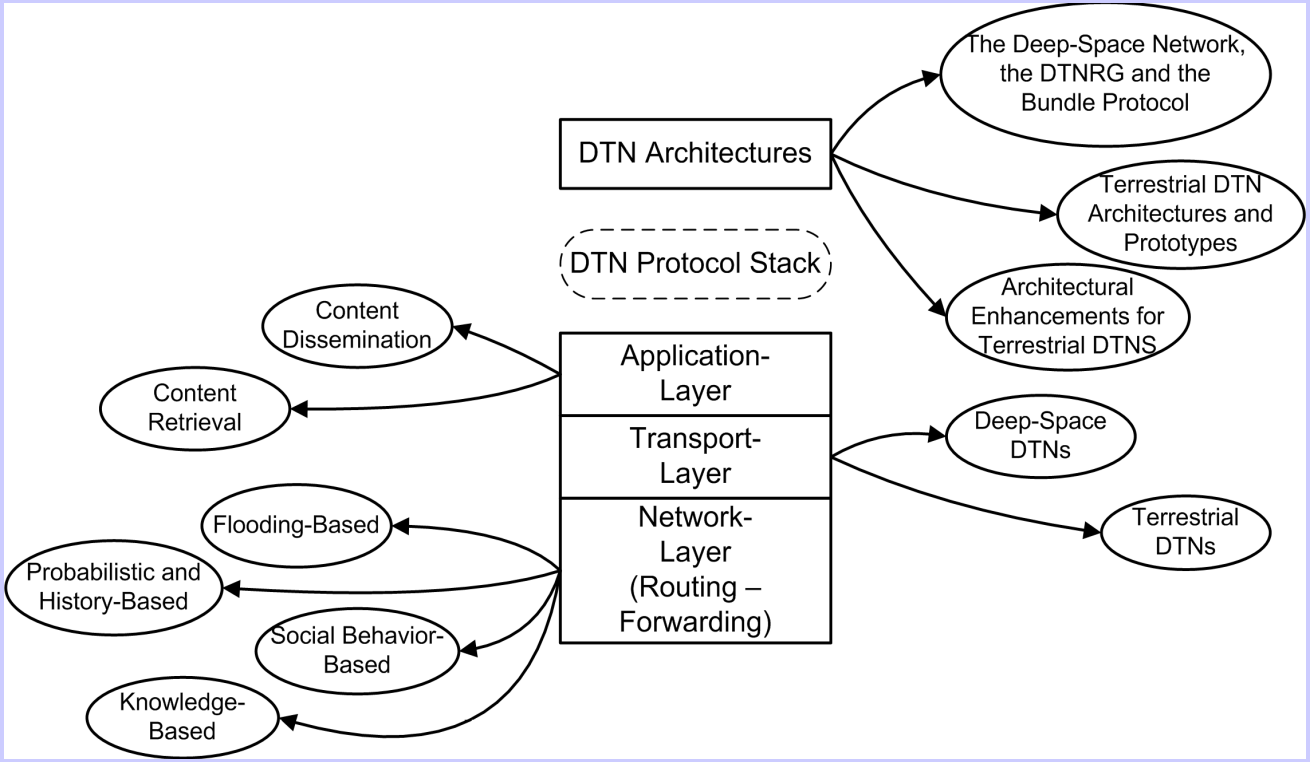
- **Space communications + DTN + Pub/Sub**
  - **DTN**
    - **High propagation delays** in space links -> the algorithms and protocols must be delay-tolerant
    - **High bit error rates** and the long-term disconnections the research was also complemented with the term "disruption".
  - **Opportunities for DTNs have been extended** in the terrestrial Internet
    - A way towards convergence objectives

Source: I.Psaras, et al."Delay-/Disruption-Tolerant Networking - State of the Art and Future Challenges", 2009, www.ee.ucl.ac.uk/~uceeips/dtn-srv-ipsaras.pdf



Convergence in the perspective of Future Internet

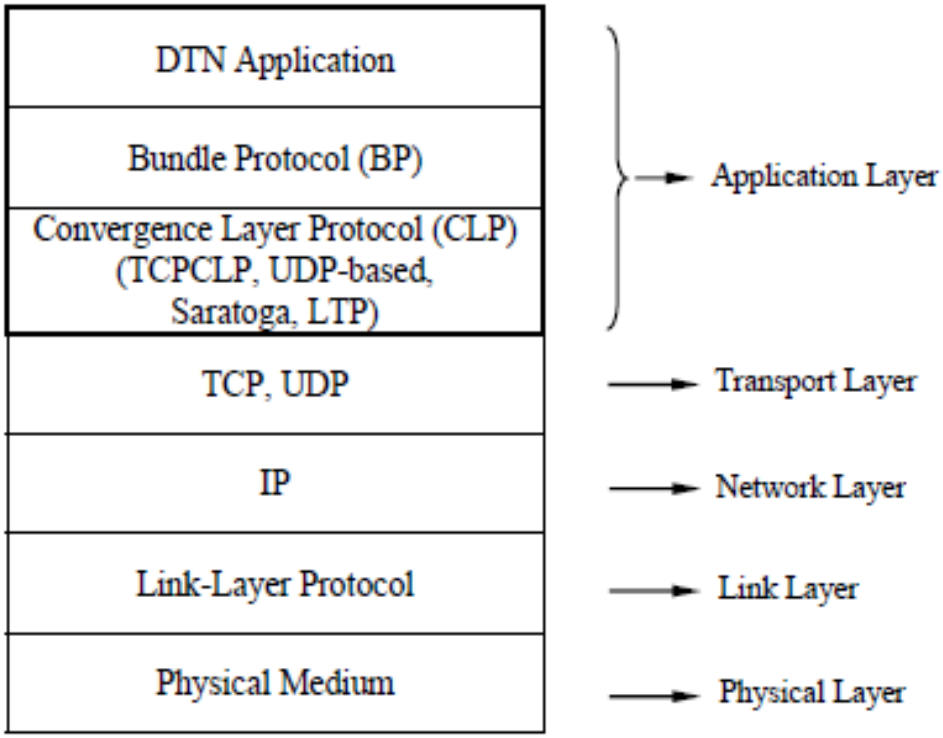
- **Space communications + DTN + Pub/Sub**
  - **DTN**
  - **Entities involved:**
    - Consultative Committee for Space Data Systems (CCSDS)
    - NASA, IETF , IRTF, DTN Research Group, .
    - Problems of interest *(I.Pasaras , etc. -Survey- see the previous slide)*



Convergence in the perspective of Future Internet

- **Space communications + DTN+Pub/Sub**
  - **DTN**
  - **Architectural stack example: DTN as an overlay**

Layering of DTN BP and CLPs in the Internet - protocol stack



Source: R. Wang et Al., Delay Tolerant Networking (DTN) Protocols for Space Communications, *icost.info/public_html1.1/Library/BookChapter/DTN.pdf*

Space communications + DTN+Pub/Sub

- **Publish/subscribe (P/S)** communication model
  - Essential in ICN/CON:
  - A content source announces (or *publishes*) a content file
  - An user requests (or *subscribes* to) the content file.
  - P/S
    - ***decouples the content generation and consumption*** in time and space
    - so contents are delivered efficiently and scalably (e.g., multicast/anycast)
    - Appropriate for DTN context

Convergence in the perspective of Future Internet

- **Space communications + DTN+Pub/Sub**
- **Example: DTN Pub/Sub Protocol (DPSP)**
  - **Replication-based distribution** in opportunistic networking scenarios for cost-efficient and scalable content distribution
    - DTN Multicast distribution based on Publish-Subscribe model
    - For reliable and timely distribution
  - Based on **local replication decisions**
    - While considering cases of limited resources (storage, bandwidth)
  - **Global knowledge about the network- not needed**
    - Instead: Relying on Publish-Subscribe model
  - Using **information about subscriptions** (e.g., receiver interest)
  - **Configurable bundle selection** and prioritization mechanism
    - Select and order bundles for transmission/storage in order to meet objectives

Convergence in the perspective of Future Internet

- **Space communications + DTN+Pub/Sub**
  - **Research directions**
    - DTN concepts for Information-centric
    - Network of Information based on DTN
  - Example of recent projects working on that
    - PSIRP/PURSUIT
    - Scalable and Adaptive Internet Solutions Project (SAIL),
    - ..
- Conclusion DTN+ P/S technologies should be continued to be investigated to achieve S/T communication convergence

Thank you !

Convergence in the perspective of Future Internet

- **References**

1. *S.Burleigh,et al.,* Delay-Tolerant Networking: An Approach to Interplanetary Internet, IEEE Communications Magazine, June 2003
2. R. Wang et Al., Delay Tolerant Networking (DTN) Protocols for Space Communications, *icost.info/public_html1.1/Library/BookChapter/DTN.pdf*
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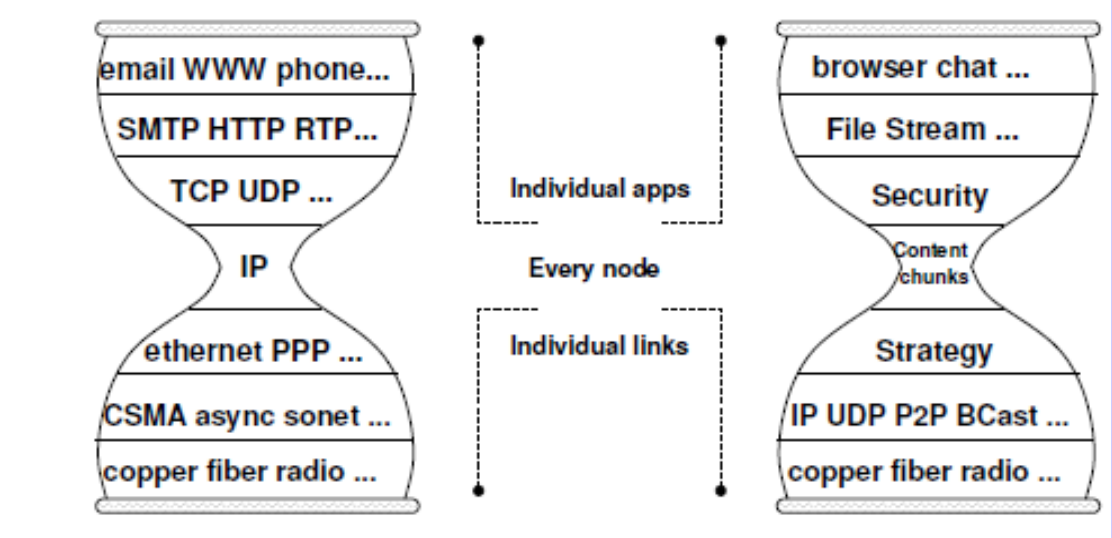
5. I. F. Akyildiz, O. B. Akan, C. Chen, J. Fang, and W. Su, “InterPlanetary Internet: State-ofthe-art and research challenges,” *Computer Networks Journal (Elsevier)*, vol. 43, No. 2, pp.75-113, October 2003.
6. S. Burleigh and K. Scott, “Bundle protocol specification,” IETF Request for Comments, RFC 5050, November 2007, [Online]: .
7. M. Demmer and J. Ott, “Delay tolerant networking TCP convergence layer protocol,”Internet Draft <draft-irtf-dtnrg-tcp-clayer-01.txt>, February 2008, [Online]: http://www.ietf.org/internet-drafts/draft-irtf-dtnrg-tcp-clayer-01.txt
8. I. Psaras, et.al.,”Delay-/Disruption-Tolerant Networking -State of the Art and Future Challenges”, 2009, www.ee.ucl.ac.uk/~uceeips/dtn-srv-ipsaras.pdf

Convergence in the perspective of Future Internet

CCN concepts Example

CCN transformation of the traditional network stack from IP to chunks of named content



Traditional TCP/IP stack

CCN

Source: Van Jacobson Diana K. Smetters James D. Thornton Michael F. Plass, Nicholas H. Briggs Rebecca L. Braynard, Networking Named Content, Palo Alto Research Center, Palo Alto, CA, October 2009

Ethernet is eating my Layer 3!

(or, “Yet Another Violation of OSI”)

Stan McClellan, PhD
Texas State University, USA

NexComm 2012 (Chamonix, Fr)
30 April 2012

TEXAS STATE UNIVERSITY
SAN MARCOS
The rising STAR of Texas

OSI vs. Internet vs. Telecom

	OSI	Internet	Telecom (SS7)
7	Application	Application (Process)	Application (MAP, TCAP, ISUP, etc.)
6	Presentation		
5	Session		
4	Transport	Transport	SCCP
3	Network	Internet	MTP3
2	Data Link	Network (Interface) (Link)(MAC)	MTP2
1	Physical	Physical (Hardware)	MTP1

The OSI model never really matches anything exactly …

SS7 over IP

	OSI	Internet	Telecom (SS7)
7	Application	Application (Process)	Application (MAP, TCAP, ISUP, etc.)
6	Presentation		
5	Session		
4	Transport	Transport	SCCP
3	Network	Internet	MTP3
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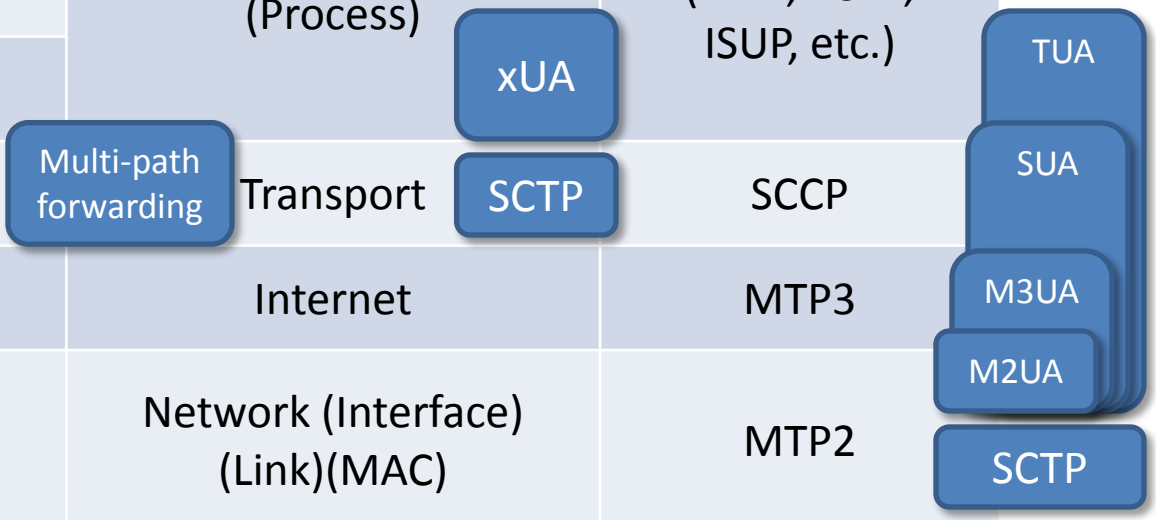

Dynamic Spectrum Access

	OSI	Internet	OFDM(A), et.al.
7	Application	Application (Process)	
6	Presentation		
5	Session		
4	Transport	Transport	
3	Network	Internet	
2	Data Link	Network (Interface) (Link)(MAC)	
1	Physical	Physical (Hardware)	

User Mapping

Channel Selection

Channel Selection

User Mapping

LAN Networks

- Historically …
  1. Ethernet = broadcast (anarchy)
  2. CSMA/CD = smarter (limited throughput)
  3. Switching = segmentation (no collisions)
  4. Fabric = crossbar switch (non-blocking, ala TDM …)
- Current Trends …
  - "Cloud Computing" & "Virtualization" & "Big Data"
  - "Software Defined Networks" & "Fabric Switching"
- Driving changes in LAN architecture
  - Datacenter (large LAN) is getting special treatment

Datacenter Networks

	OSI	Internet	TRILL, et.al.
7	Application	Application (Process)	
6	Presentation		
5	Session		
4	Transport	Transport	
3	Network	Internet	
2	Data Link	Network (Interface) (Link)(MAC)	
1	Physical	Physical (Hardware)	

Ethernet, defined by **IETF** rather than **IEEE**

IS-IS

Tunnel

Tunnel

IS-IS

Multi-path forwarding

Observations

- Flexibility is getting more important as network technologies “converge” together
  - Flexibility trumps structure …
  - But some minimal structure is imperative
- Ethernet (among many other examples …)
  - Used to be simple, easy, consistent
  - Now, it’s complex, difficult, fragmented
  - Application-specific workarounds

Question

- The OSI reference model
  - Not really practical, but always used
  - Rigid & Hierarchical vs. Flexible & Flat (flatter)
  - Application-specific tweaks violate framework

- Is there a better conceptual approach?