Challenged Networks
S-38.3155

Introduction

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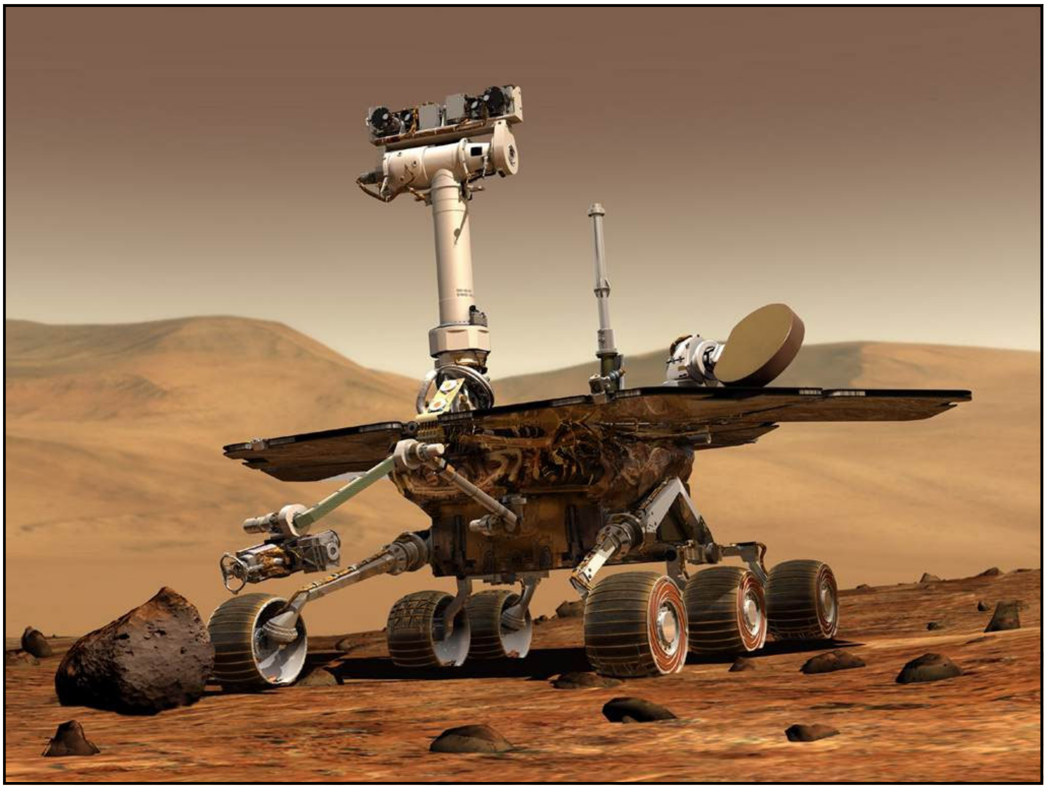
Overview

- Seminar (3 ETCS points)
- Introductory lecture (today)
- Seminar presentations spread across two days
  - 30min Presentation and discussion per topic
  - One “opponent” per topic
- Overview and assignments: today
- Dates and venue: 27.02.2008, 16:00 (D302)

Requirements

- Seminar presentation
  - 30 minutes
  - Slides (digital: PS, PDF, or PPT)
    - Will be provided on the course web page after the seminar
  - Preparation meeting by individual appointment to discuss contents
- Written summary: 5 – 10 pages
  - Double column style of IEEE journal / conference proceedings
  - Should be sent one week prior to the seminar (13.02. and 20.02. respectively)
    - Also to the opponent
    - Will be published on the course web page
- Material
  - Material available on the course web page (mostly including links)
  - Complement by own literature research as needed (e.g. for some basics)

Examples for DTNs…




NOKIA
N95
Menu
Contacts
Messaging
Calendar
Music player
Gallery
Maps
Search
Web
Downloads
Tools
Applications
Office
Options
Exit

Classical IP Networking

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Internet Design Philosophy

- Military network
  - Survivability: “Communication must continue despite loss of networks or gateways”
- Hide transient failures completely from higher layers
  - Route past disruptions
  - Only complete partition of the network will lead to application layer failure
- Fate sharing
  - State information maintained only at end points
  - Weak assumptions about the network’s ability to report that is has failed

Packet Switching

- Why the Internet is packet switched
  - Originally designed to connect packet switched networks (ARPANET, ARPA packet radio)
  - Applications were a natural fit for packet switching (e.g., remote login)
  - Packet switching was well understood from the experience with ARPANET
- Is packet switching the right abstraction?
  - It has proven highly successful in a world of fixed infrastructure.
  - Many problems in challenged networks.

The Internet Protocol

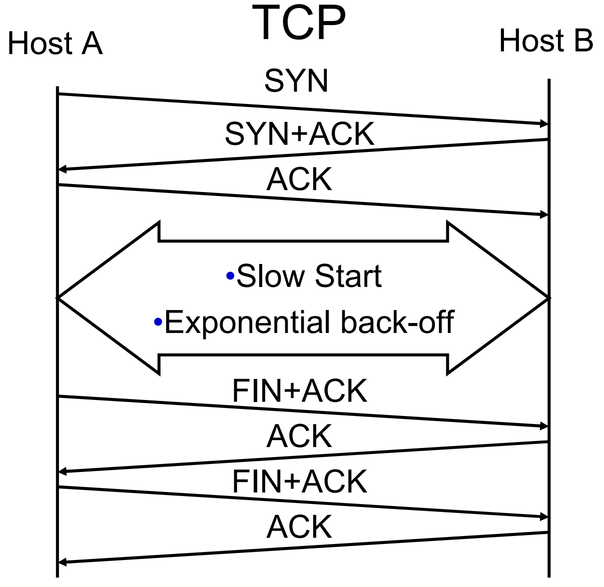
- IP (the protocol) makes very few assumptions
  - Lower layers can drop, re-order, corrupt or duplicate packets
  - No IP layer timers
- Some protocol issues exist (at least in theory)
  - TTL field: Originally a measure of time, now a hop-count
  - Identification field: Used to identify fragments
- Implementations make assumptions
  - End-to-end paths can be found
  - Topology is largely static


```
vegard@gyversalen:~$ ping -i 900 10.0.3.1
PING 10.0.3.1 (10.0.3.1): 56 data bytes
64 bytes from 10.0.3.1: icmp_seq=0 ttl=255 time=6165731.1 ms
64 bytes from 10.0.3.1: icmp_seq=4 ttl=255 time=3211900.8 ms
64 bytes from 10.0.3.1: icmp_seq=2 ttl=255 time=5124922.8 ms
64 bytes from 10.0.3.1: icmp_seq=1 ttl=255 time=6388671.9 ms

 --- 10.0.3.1 ping statistics ---

9 packets transmitted, 4 packets received, 55% packet loss
round-trip min/avg/max = 3211900.8/5222806.6/6388671.9 ms
```

TCP



When TCP Breaks

- TCP underlies most of the applications we use every day
- Three way handshake (1.5RTT) before any data can flow
  - Assumes that RTTs are “low”, i.e. in the order of milliseconds
- Flow control based on ACKs – Slow start, exponential back-off
  - Assumes that packet losses are rare (<2%) and are due to congestion
  - Assumes flow control in the order of RTT makes sense (again, “low” RTT)
- Generic 2 minute timer – Break the connection due to inactivity

Can We Fix It?

- Performance Enhancing Proxies (PEP)
  - Middle boxes that modify the data streams to hide problems.
  - Transport layer or application layer
  - Link specific – can't be deployed securely in the global Internet
  - What happens to transparency? Security?
- Protocol Modifications
  - Change the assumptions (e.g. timer values)
  - Only changes the operating point

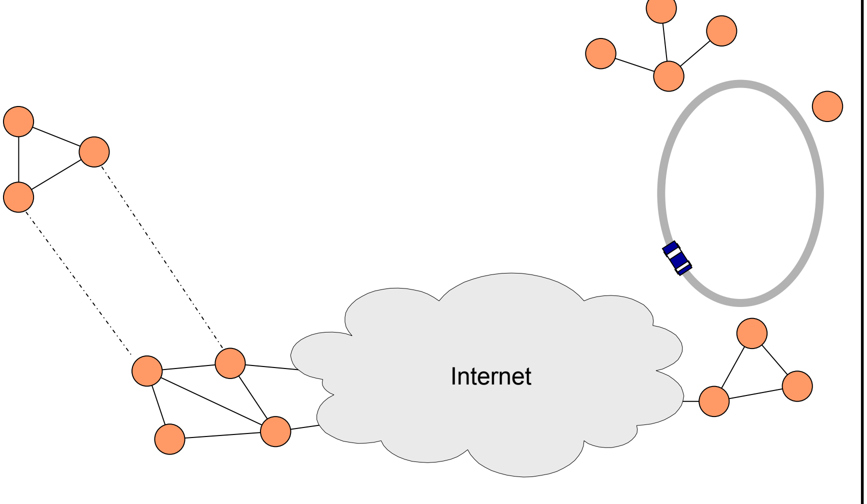
Abstractions…

- Simplification of a complex reality
  - We don't start with Maxwell's equations when writing networking software
- Based on making simplifying assumptions
- Network layering is a typical abstraction
  - Physical layer creates an illusion that we can transmit "bits"
  - TCP creates an illusion of a reliable transport over unreliable network

… Leak. Always.

- Leaks occur when the underlying reality shows through
  - Unexpected behavior that cannot be explained without understanding the underlying reality
- Result of the simplifying assumptions not holding
  - TCP slow start when RTT is in the order of seconds
- Patch the leak or come up with a new abstraction?
  - Patching with PEPs and protocol modifications will only take us so far.
  - The assumptions made by current Internet protocols simply do not hold;
  - New abstraction needed!

Some Sample Scenario



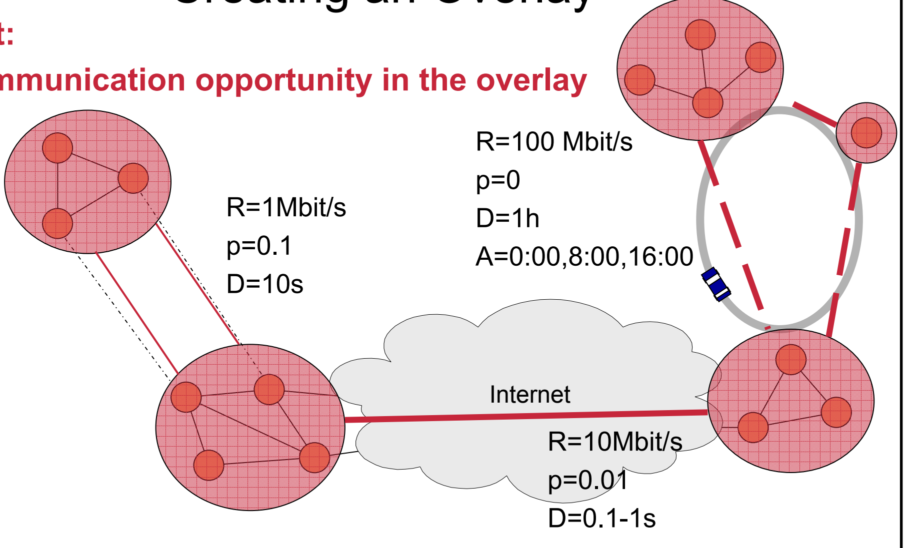
Revisiting Communication Paradigms

- Delays may be too long for interactive protocols
  - RTTs of minutes or hours or even days?
- An end-to-end path to a peer may never exist
  - At least not at the order of time IP routers and end systems operate
- Delay tolerance implies disruption tolerance
  - If a peer, a link, or a path is not available, just wait until it comes back
  - Store the “packets” in the meantime
  - Hand the data to someone else who may have better chances of delivery
  - Move (or have someone move) with the data towards the destination
- Use only asynchronous communications
  - Simply modeled after email
  - Store and forward: wait for the next suitable opportunity to send
  - Store, carry, and forward: add physical data carriage as communication option

Creating an Overlay

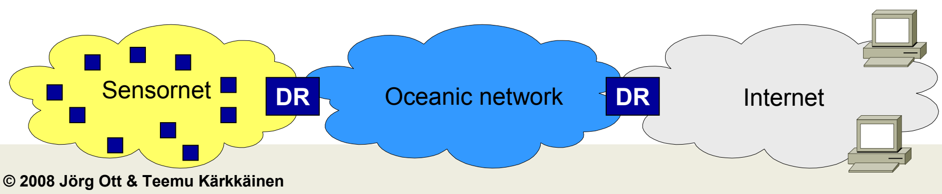
Contact:

any communication opportunity in the overlay



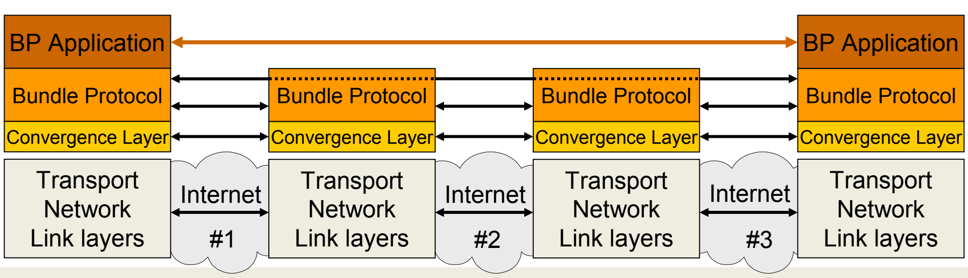
DTN RG Architecture (1)

- Purpose: asynchronously interconnecting different internetworks
  - Which may be based upon arbitrary underlying technologies
  - Which may encompass just a link layer technology or a complete protocol suite
  - Which may cross different administrative boundaries
  - Which may be used for different (presently unforeseen) applications with diverse requirements
  - Which cannot necessarily rely on an always accessible infrastructure
- Example



DTN RG Architecture (2)

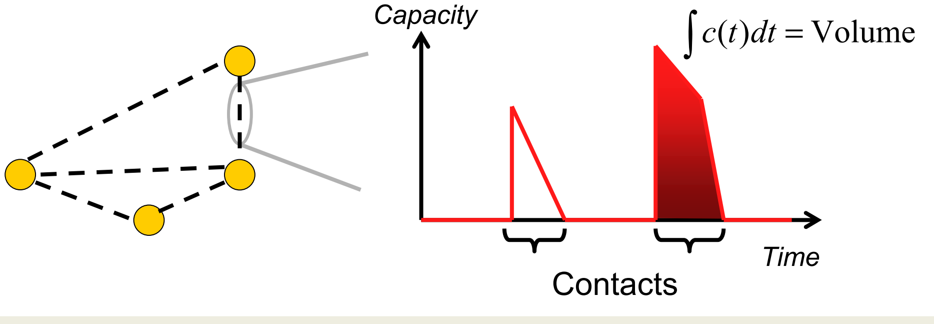
- Applications exchange Application Data Units (ADUs)
  - Semantically meaningful pieces of information (=messages)
- **Bundle** as communication unit encapsulate ADUs
  - **Bundle layer** on top of underlying networks using **Bundle Protocol (BP)**
- Mapping to lower layers defined by “convergence layer”



Routing in Challenged Networks

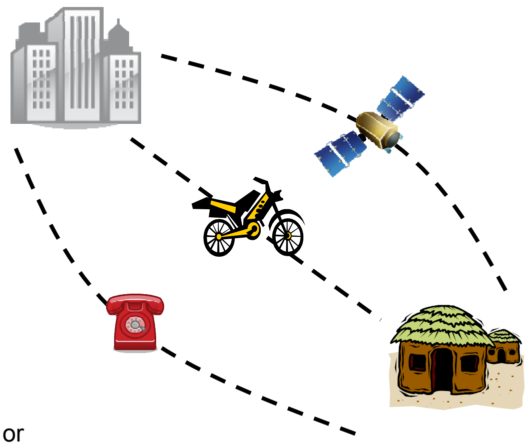
Contacts

- In the Internet addressable entities are online all the time
  - Disruptions are treated as transient failures => time invariant cost
- In DTNs we expect communication to be possible only intermittently
  - Links have time varying delay and capacity => time varying cost



Contact Types

- Persistent
  - DSL
- On-demand
  - Dial-up connection
- Scheduled
  - Deep-space applications
- Opportunistic
  - Ad-hoc connections
- Predicted
  - Based on past observations or other information



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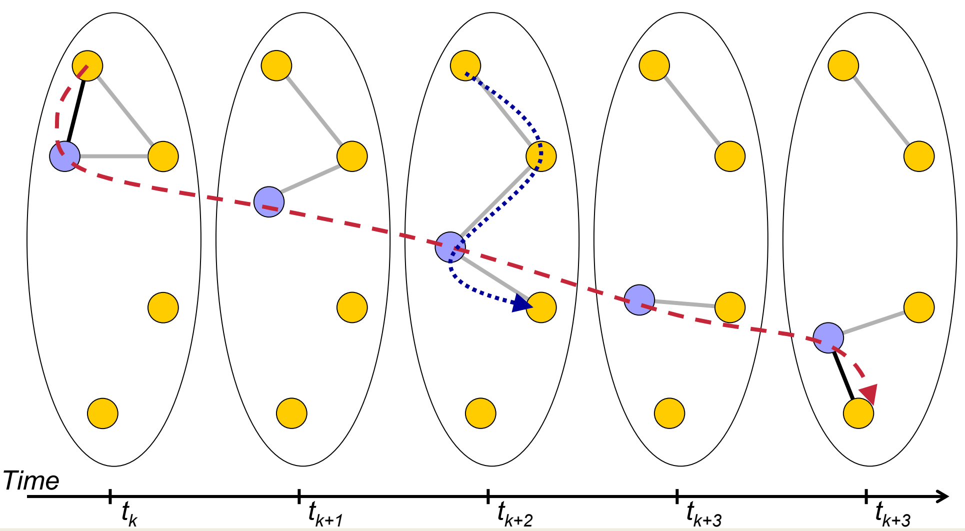
Space Paths vs. Space-Time Paths



Challenges of Routing in DTNs

- The scope of applicability of the DTN architecture is very large
  - In deep-space missions topology and contacts are known ahead of time
  - In rural networks topology is known, but connectivity outages unpredictable
  - In mobile ad-hoc networks all contacts are opportunistic
- A single, grand routing algorithm might not be realistic
  - Need to understand the different classes of DTNs
    - Informal classification by Borrel, Ammar and Zegura [1]
    - Formal classification by Ramanathan, Baus and Krishnan [2]
  - Need to understand the different classes of routing approaches
    - Classification by Zhang [3]

[1] V. Borrel, M. Ammar, E. Zegura, "Understanding the Wireless and Mobile Network Space: A Routing-Centered Classification," CHANTS'07

[2] R. Ramanathan, P. Basu, R. Krishnan, "Towards a Formalism for Routing in Challenged Networks," CHANTS'07

[3] Z. Zhang, "Routing in Intermittently Connected Mobile Ad Hoc Networks and Delay Tolerant Networks: Overview and Challenges," *IEEE Communications Surveys and Tutorials*, 8(1), 2006

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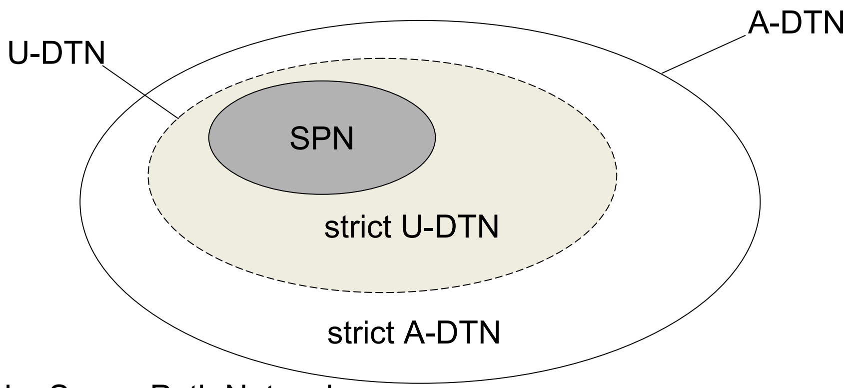
Informal Network Classification

- Space-Path Network (SPN)
  - Space-paths exist between all the nodes
  - The typical "MANET" network
- Unassisted DTN (U-DTN)
  - Space-Time paths exist between all the nodes
  - The typical DTN network
- Assistance-needed DTN (A-DTN)
  - No paths exist between some nodes
  - Separated network islands, needs "assistance" to connect

Informal Network Classification



SPN = Space-Path Network

U-DTN = Unassisted DTN

A-DTN = Assistance-needed DTN

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Classification of Routing Approaches

- Classification based on knowledge of schedule
  - Deterministic: Future topology and contacts well known in advance
    - e.g., deep-space networks
  - Stochastic: Future topology and contacts not known in advance
    - e.g., (sparse) mobile ad-hoc networks
- Formal classifications exist as well
  - Borrel, Ammar and Zegura
    - Routing centered network classification based on evolving graphs
  - Ramanathan, Baus and Krishnan
    - Classification based on three attributes: 1) end-to-end path required, 2) single copy (no replication), 3) unavailable schedule.

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Routing Approaches

Deterministic

- Space time routing
- Tree approach
- Modified SPF

Stochastic

- Epidemic / Random Spray
- Prediction-based
- Model-based
- Control movement
- Coding-based

Network and Mobility Models

- Contact characteristics determines routing protocol design
  - Availability vs. unavailability
  - Permanent → regular/recurring → predictable → opportunistic
  - Degree, frequency and distribution
  - Mostly connected vs. mostly disconnected
  - Scale (nodes, node density)
- Contact characteristics are highly scenario-dependent
  - Space vs. desert vs. highway vs. downtown vs. Olympic stadium
- Approaches towards providing the basis for simulations
  - Synthetic generation of mobility: RW, RWP, map-based, group models, …
  - Reality mining: trace-driven from different scenarios
  - Understanding the characteristics of reality to create better models

Some Performance Metrics

- Contacts:
  - Inter-contact time, contact duration
- Message delivery
  - Message delivery rate (e.g., 70%)
  - Message propagation delay (e.g., hours to many days)
  - (C)CDF of rate over delay
- Protocol overhead
  - # message copies in the system (per sent message), buffer occupancy
  - # transmissions per sent message
  - # dropped messages
  - Fraction of control messages

Further Open Areas

- Security
- Reliability
- Congestion control
- Specific applications and meaningful deployment scenarios
- …

Topics

Topic	Presenter	Opponent
1. Routing I	Presenter	Opponent
2. Routing II	Presenter	Opponent
3. Routing III	Presenter	Opponent
4. Performance Analysis	Jarno	Opponent
5. Security (Frag Auth)	Kari	Shengye
6. Vehicular Networks	Presenter	Opponent
7. Mobility Modeling I	Varun	Opponent
8. Mobility Modeling II	Presenter	Opponent
9. Content Distribution	Shengye	Opponent
10. Storage and Retrieval	Matti	Opponent

Assignment to the two slots is somehow flexible.