Delay-tolerant Networking

Postgraduate Seminar

http://www.netlab.hut.fi/~jo/teaching/en/

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Overview

- Seminar (3 ETCS points)
- Introductory lecture

- Seminar presentations spread across two days
  - 30 – 45min Presentation and discussion per topic
  - One opponent per topic

- Overview and assignments: today
- Dates and venue: 18.10.2005, 15:00 (D302)
  20.10.2005, 15:00 (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 (11.10. and 13.10. 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…

Vehicular Networks

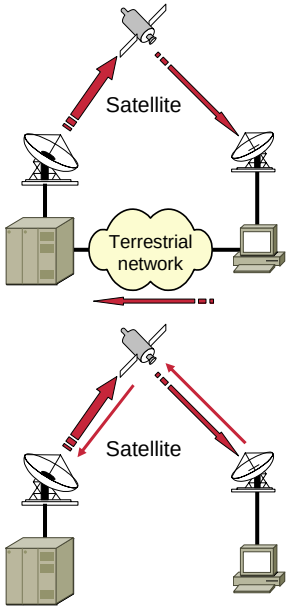
- Car area communications
  - Connecting on-board devices
  - Real-time requirements
- Inter-car communications
  - Wireless communication, e.g. based upon infrastructure-less UMTS
  - Direct: car to car within a limited range (less than one to a few km)
  - Indirect 1: using other cars for real-time routing
    - Critical mass (density) of cars is important
  - Indirect 2: using other cars for application-layer store and forward
  - Applications: traffic data exchange, emergency notifications
    - Also: entertainment (e.g., exchaning MP3 files)
- Car-to-fixed infrastructure
  - Delivering and receiving e.g. traffic data
  - Via GRPS, UMTS, GSM, SMS, also via broadcasting and WLANs

Other Moving Things

- Communications from and to trains
  - Cellular + satellite communications
- Airplanes
  - Internet access in the sky (e.g., connexion by Boeing) via satellites
  - Opportunistic communications with ground stations
- Ships
  - Intermittent connectivity via satellites
  - Opportunistic contacts between ships
- People!

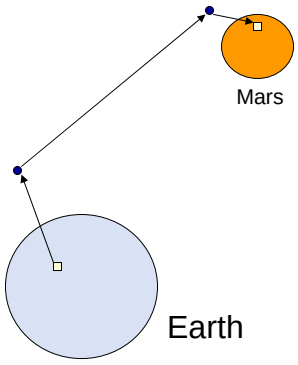
Satellites

- Geostationary satellites
  - A bit of delay
  - 250ms one-way link propagation delay
  - Noticeable error rate (e.g. weather conditions)
- Low earth orbit (LEO) satellites
  - Lower data rates, lower link propagation delay
  - Multi-hop routing, handover, on-board processing
  - Store and forward operation
    - E.g. collect weather data while orbiting and transmit data collection during short periods of connectivity to earth stations



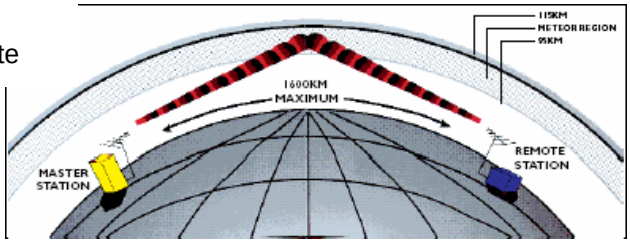
Deep Space Networks

- Communications with space crafts, space stations, satellites
  - E.g. Mars explorers
  - Low data rates, high error rate
  - Long propagation delays
    - Moon: ~3 seconds
    - Mars: ~2 minutes
    - Pluto: 5 hours
  - Link interruptions
    - Planetary dynamics
  - Scheduled communications
    - Pre-calculate next chance to communicate
    - Different requirements for “routing”
  - Retransmissions and interactive protocols are not workable



Meteor Burst Communications

- Using ionized particles behind tiny meteors for reflection
  - About 10^{12} meteors enter the atmosphere per day
  - Burning in atmosphere between 80 and 120 km height
  - Only small fraction is usable (right trajectory, energy, etc.)
- Communication characteristics
  - Communications time < 1s
  - Burst communications
  - Average 1000 bits/minute
  - Permant probing and quick response required
  - Error rate
  - Non-predictability



Source: Communications of the ACM, January 2004

Acoustic Underwater Networks

- Interconnecting ocean bottom sensor nodes, autonomous underwater vehicles (AUVs), and surface stations (gateways)
  - Environment monitoring, underwater surveillance
- Propagation delay at the speed of sound (~1480m/s)
- Range and frequence significantly influence transmission loss
  - Doppler effects with moving vehicles
  - Multipath effects
  - Differences in deep and shallow water
- Range from 10s or meters to 1 – 10km, also 100 – 200km
- Data rates from 20 bit/s to a few kbit/s
  - Extremes: short range 500 kbit/s, long range 1 bit / minute
- Use “data buoys” for store and forward
  - Use ships for physical carriage

Carrier Pigeons

- RFC 1149, RFC 2549
- Implemented by Bergen Linux users group
  - Printed datagrams on paper
- Further experiments in Israel (Wi-Fly)
  - Used tiny memory of 1.3 GB per pigeon
- Characteristics
  - High delay
  - Don't fly at night (your favorite surfing time)
- Up to 1.5 Mbit/s data rate, faster than simple ADSL

Data Mules

- Sámi Network Connectivity
  - Provide Internet Connectivity for Sámi population of Reindeer Herders
  - Nomadic users, no reliable communication facilities
  - Mix of fixed and mobile gateways
  - Routing based on probabilistic patterns of connectivity
  - E-Mail, Web-access, file transfer
- DakNet
  - Internet access for remote villages in India and Cambodia
- Pocket-based communications
  - Exploiting people's motion for data transfer
  - Use buses, motor cycles, postal mail

Data Mules (2)

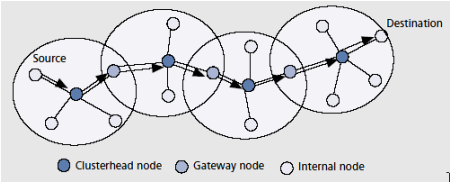
- Sensor networks without end-to-end path
  - Traditional ad-hoc routing not applicable
  - Collect and store data, forward opportunistically
  - Offload to fixed or mobile access gateways
- Zebranet
  - Monitoring a wild-life habitat with networked computers
  - Ad-Hoc Networks, computers on Zebra exchange information dynamically
- Applications in Oceanic studies
  - Measurements using sensors on seals, whales, etc.
  - Also: fixed underwater measurement equipment
- Seismic and fire monitoring in remote areas

Mobile Hosts and Networks

- Host Mobility
  - Internet host roam across the Internet, use different points of attachment
  - Different link layer technologies, get different addresses
  - Addressed by Mobile IP, HIP for persistent identifiers, etc.
- Mobility support for networks
  - E.g., planes, trains, buses that carry a network of hosts
  - Mobile router connects on-board network to the Internet
  - Local network topology remains constant, external points of attachment may change
- Issue
  - Still need to deal with loss of connectivity
    - Expected, unexpected, short or long-lasting, user-controlled or not, etc.

Ad-hoc Networks

- Mobile Ad-hoc network (MANET)
  - An autonomous system of mobile routers (and associated hosts)
  - Frequent topology changes
- MANET protocols
  - Routing protocols that exchange topology/reachability information
  - Have to address a set of *interesting* characteristics
    - Low bandwidth, power constraints, frequent topology changes, fast conversion, scalability
- Issue: Assumptions about degree of connectivity
  - Trend towards consideration of intermittent connectivity
  - Development of DTN routing protocols for MANETs



Asymmetry

- Dimensions of asymmetry
  - Communication direction
  - Data rate
  - Transmission latency
  - Error rate
- Asymmetric link layers
  - xDSL, cable networks, powerline networks, DVB-RCS, (GPRS)
- Simultanous use of hybrid technologies
  - Low speed interactive link (e.g. GPRS, GSM, UMTS)
    - Including possibly asynchronous messaging (SMS, MMS)
  - Broadcast downlink
    - DVB-S/S2/T/C/RCS
  - Very different cost functions associated with these ways

Constrained (Network) Elements

- Limited lifetime
  - Environmental conditions
  - Third-party influence
  - Material, construction
- Power constraints
  - Limited transmission / reception time
  - Limiting forwarding capacity
- Limited transmission range
  - Direct vs. indirect communications (other nodes may need to route)
- Memory and processing contraints

Brief Summary of Issues

- Intermittent, unpredictable connectivity periods and blackouts
  - Short-lived connectivity
  - Non-existent end-to-end paths
- Transmission characteristics
  - Potentially: Low data rate, high error rate, asymmetry
  - High propagation delay
    - Due to link latency (in space, under water), intermittent connectivity
- Node and environmental constraints
  - Lifetime, availability, density
  - Non-availability of infrastructure
- Changes communication semantics, application paradigms
- Adds complexity to routing protocols

Contents