MobilityFirst Internet Architecture: Overview

MobilityFirst Workshop

Organized as a part of:
Project: Engaging undergraduates in research that speaks their language
Sponsoring Agency: The Thurgood Marshall College Fund
Sponsoring program: Undergraduate Research to Retain and Graduate Students in STEAM

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Slides based on: See Reference slide

Overview

Goals of our project at York

1. Demonstrate communication in disconnected scenarios
2. Use content caching, opportunistic routing and transport to support such communication

MobilityFirst components useful for our study

- Generalized storage aware routing
- Name based content retrieval
- Hop by hop transport

Mobile Internet: Can we assume always on robust connectivity (yet)?

Most edges are now wireless: Intermittent disconnection is almost a second nature

- Short and long term disconnections due to mobility
- Change in link quality when switching from one connection technology to another: wired to wireless, Wi-Fi to wimax...
- Disconnection due to device switching to low power mode

Generalized Delay Tolerant Networks

- All networks are affected by some degree of intermittent disconnections

  –Cellular, W-Fi, mesh networks, mobile infrastructure-less networks (MANET), sensor and tactical networks
- All networks display characteristics associated with Delay Tolerant Networks type disconnections

  –Various timescales of disconnections: few seconds to several hours

How many different types of wireless networks are there?

Lets step back to look at some background

There are more network types than meets the eye!

Wireless devices can be put together to make many types of configurations, forming interesting types of networks:

- Infrastructure-less networks
  1. Mobile Ad-hoc Networks(MANET)
  2. Sensor networks
  3. Delay tolerant networks (DTN)
- Infrastructure networks
  1. Cellular networks
  2. Wireless mesh networks
  3. Wireless Local Area Networks

Infrastructure-less networks: Mobile Ad-hoc Networks

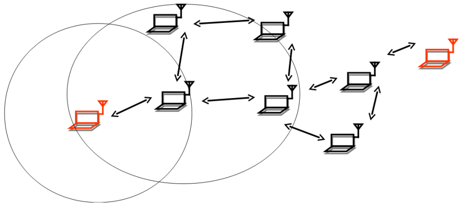

Figure: Mobile ad-hoc networks

- Self-organized, mobile, infrastructure-less network
- Multi-hop wireless links connecting devices in a network
- Dynamic routing due to mobility

Devices may not have end-to-end connectivity at all times

Infrastructure-less networks: Sensor Networks

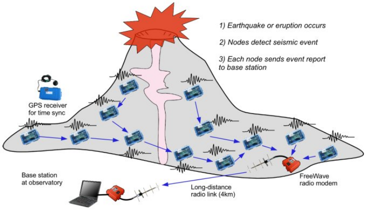

Figure: Sensor networks *Image Source:*[1]

- Self-organized, mostly static, infrastructure-less network, originally designed for remote monitoring of challenged environments
- Multi-hop wireless links connecting devices in a network
- Dynamic routing to account for aggressive power management needs to increase the lifetime of the network

Network might get partitioned when several nodes permanently run out of battery power.

[1] http://fiji.eecs.harvard.edu/Volcano

Infrastructure-less networks: Delay Tolerant Networks

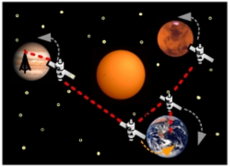

Figure: Connecting remote areas together. *Image Source:*[2]

- No assumption of end-to-end connectivity: complete disconnection is standard
- Mobile nodes exchange data upon encounters
- Data gets passed around and duplicated until the destination receives it
- Opportunistic/probabilistic routing to account for lack of connectivity

Routers no longer can receive and forward data immediately, instead long term storage is necessary.

[2] http://www.dsg.cs.tcd.ie/node/294

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What if we assume that all networks are DTN (to some extent)?
We designed routing that works across the entire spectrum of connected and disconnected networks

Multi-hop network routing: Features

- Maintain routes at all times:
  - Proactive: maintain shortest paths between all pairs
  - Reactive: maintain active routes only
- Notify the network about disconnections immediately:
  - Use shortest path or least cost metrics

DTN routing: Features

- Extreme disconnections or no end-to-end path:
  – Assume disconnections are normal
  – Availability of connectivity is an exception
- Storage, probability and past history used for data forwarding decision:
  – Store data until "suitable" forwarding node appears
  – Use higher order routing metric such as contact probability
- Keep data in storage

STAR: Storage Aware Routing

- Enable connectivity across heterogeneous networks:
  – Routing adapts to changes in network type (wired, wireless, self-organized)
- Discover shortest paths when there is continuous end-to-end connectivity:
- Temporarily store data when the destination is not reachable
- For each destination, maintain paths to all interfaces, remember current and past link quality

Storage Router: Concept

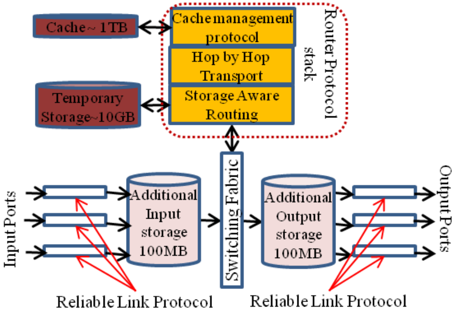

Figure: Storage Router

Routing Parameters

- Storage:
  – Available storage space on all routers in the network
- Short term costs:
  – Instantaneous values of the link cost metric
- Long term cost: Historical representation of the link cost metric over a longer time horizon
  – Moving average over a short term sliding window

STAR Algorithm

- Stable Region:
  – $0.5 <$ Short term cost / Long term cost < 1.5
- Store Region:
  – Short term cost / Long term cost $>= 1.5$
- Forward Region:
  – Short term cost / Long term cost $<= 0.5$
  – Minimum available storage on downstream router is greater than a threshold

STAR Algorithm

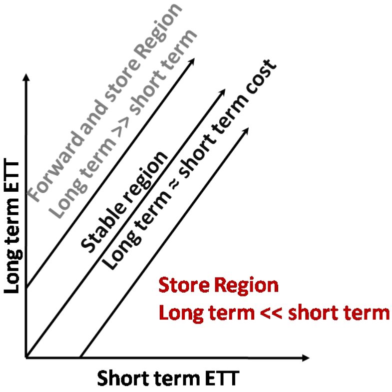

Figure: Forwarding decision in STAR

Link cost metrics

- Hop distance
  - Does not capture link variations i.e., how fast/slow is each hop
- Expected transmission count: Average number of retransmissions
  - Does not represent the speed of each transmission
- Expected transmission time: how many retransmissions and how fast
  - May take several transmissions to measure

Signal strength measurement to determine transmission rate and hence, expected transmission time

Signal strength based link cost

Cross Layer Solution

- Measure signal to noise ratio of each received transmission
- Find the best transmission rate from the bit error rate (BER) curve (see below)
- Expected transmission time: (Packet size/Rate)+overhead

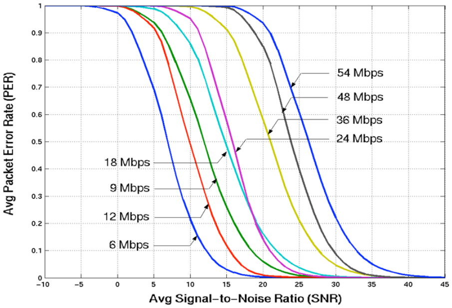

Figure: Signal strength vs. bit error rate (BER) curve

Routing control messages

Use standard neighbor discovery procedure with additional fields to collect more data

- Send heart-beat messages to keep track of neighbors
- Record signal strengths of received messages in neighbor table
- Send topology discovery messages to learn about the network topology
- Disseminate link information along with multi-hop topology control messages

Router details

- Routers maintain tables of neighbors and topology
- Use breadth first search through the topology learned from the table to compute multiple paths
- Forwarding information base (FIB) contains next hop alternatives, short term costs, long term costs and storage for each reachable destination

STAR: Why does it work in all sorts of scenarios?

- In well connected networks, routes are stable
- In wireless LAN short term link quality might fluctuate for mobile nodes]] – When nodes handover to a nearby access point in the same network, the links improve
- In dense infrastructure-less networks, poor short term link indicate mobility and storage copes with short term disconnection
- In DTN, finite long term link qualities indicate that there was a past encounter with the target node

Various simulated and emulated scenarios show promising results: See reference for details

Generalized Storage Aware Routing

STAR was designed for various network scenarios/conditions

GSTAR was designed for multi-interface scenarios to support multi-homing, multi-user scenario by supporting multicast and content centric design

HOP: Transport large blocks reliably across links

HOP uses large blocks of data $\approx$1MB as a unit of transport

Each block is delivered to the next node reliably (acknowledgments exchanged)

- Works better than TCP and UDP for large file transfers in challenged networks
- Functions well with STAR and GSTAR to provide data transport in disconnection scenarios
- Supports content caching on routers

Software Implementation

Implementation of GSTAR and HOP:

- Simulation:ns3 (http://www.nsnam.org/)
- Prototype development: click router (http://www.read.cs.ucla.edu/click/click)
- Prototype: Openflow (https://www.opennetworking.org/)
- MobilityFirst code: http://mobilityfirst.winlab.rutgers.edu/Prototype.html

MobilityFirst in action!

http://mobilityfirst.winlab.rutgers.edu/Prototype.html

Comments or Questions?

Homework

Read the paper that was summarized in this slide

Blog about what you like, dislike or think about the paper and this presentation

References

- Storage Aware Routing
  http://mobilityfirst.winlab.rutgers.edu/documents/GSTAR-MobiArch11.pdf
  http://www.computer.org/csdl/proceedings/wowmom/2011/0352/00/05986209-abs.html
- Hop by hop transport
  M. Li, D. Agrawal, D. Ganesan and A. Venkataramani.
  Block-switched networks: a new paradigm for wireless transport. In Proceedings of the 6th USENIX symposium on Networked systems design and implementation, 2009

Final reports

All participants must choose a final report title.
The report must be around 1,000 words long, may contain pictures
You should choose a sub-topic from the slides covered thus far
Reports are required for evaluation and acceptance in the second phase of this project that runs from September to end of November