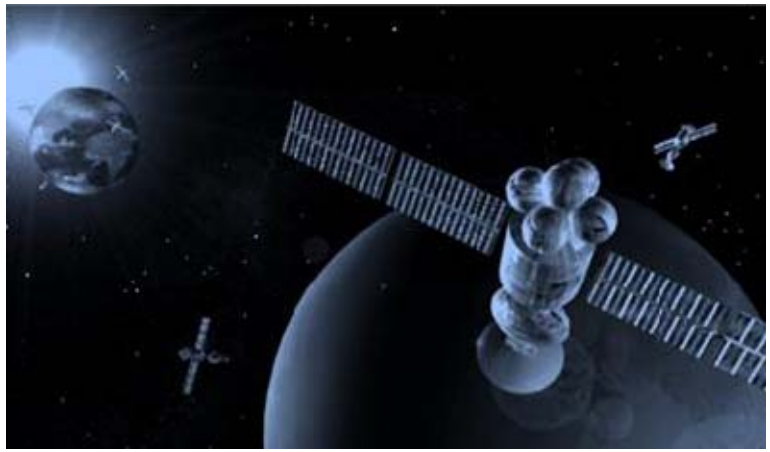
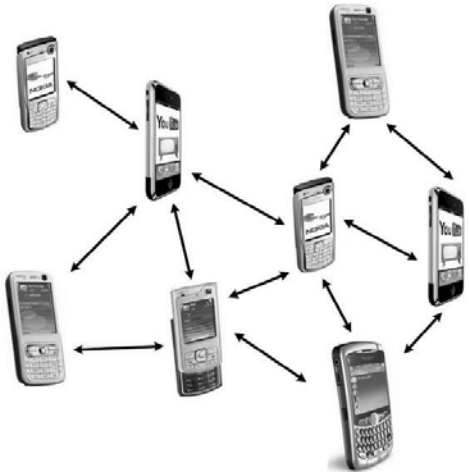
What are Delay Tolerant Networks?

- Most of network unreachable at any instant
- Connectivity patterns vary in predictability
- Communication is “opportunistic”
- Mobile nodes can bridge components using “store and forward”





Haggle

- Delay Tolerant Networking platform, primarily for mobile ad-hoc communications
- Provides a range of DTN functionality that applications can plug into, on a range of hardware such as mobile phones and laptops
- Uses “search-based resolution”
- Event-driven runtime engine

Background / Related Work

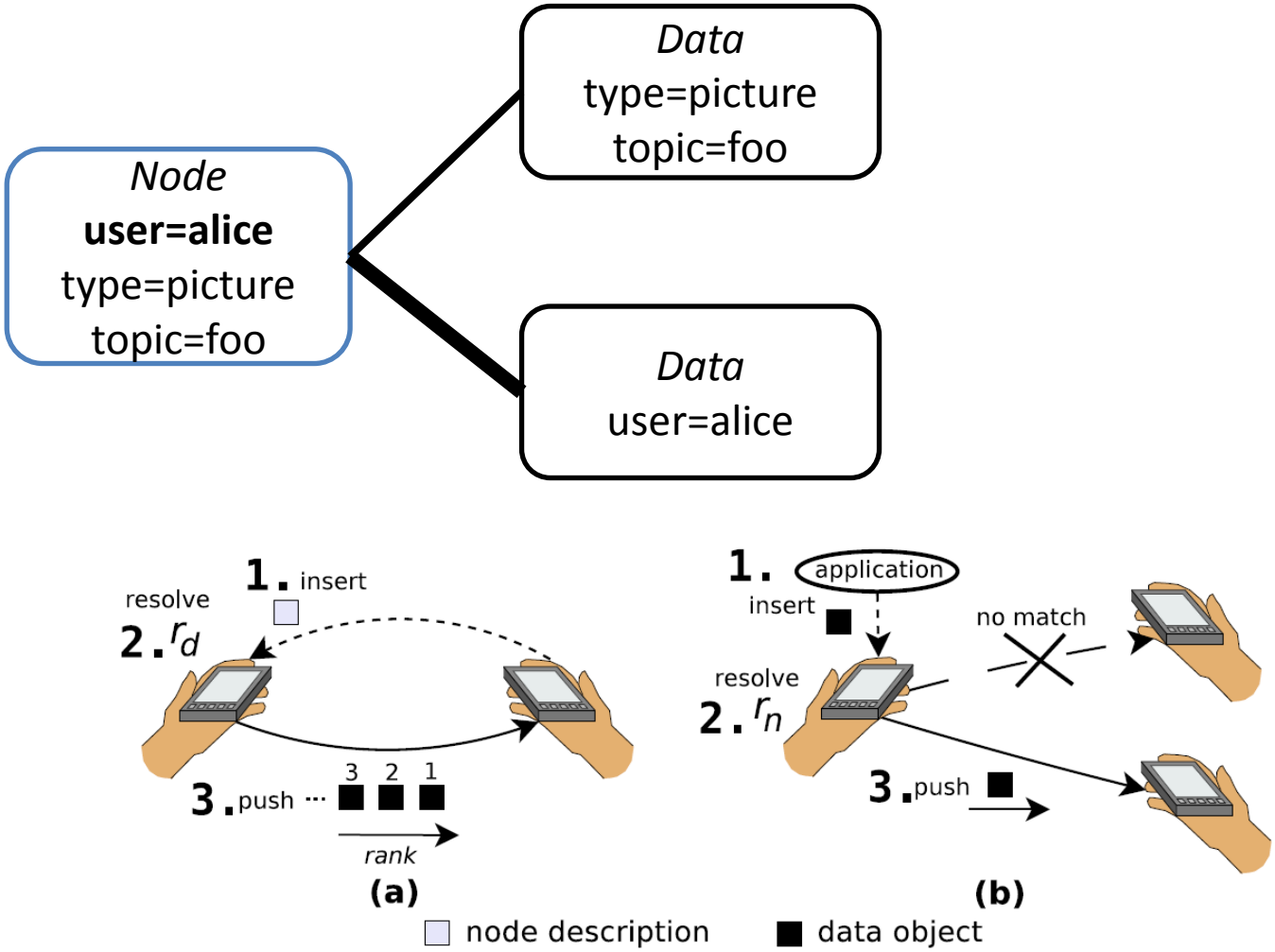
- Search-based resolution approach has roots in Intentional Naming System (INS)
- Publish / subscribe methodology, utilising flat labels and Bloom filters
- Various routing approaches have been proposed for DTNs – Haggle makes use of searching, and can plug into a variety of forwarding methods
- Other DTN projects include the DTNRG's offering, DTN2, and the Linklader protocol for deep-space comms. UCB also has a system targeted at technology for developing nations.

Search-based Resolution

- All data objects are “tagged” with attributes using a unified metadata format
- A “node description” is a special data object that defines a node’s (weighted) interests
- Resolution maps interests to attributes, and pushes matching data to nodes in order of relevance
- Data will eventually find its way to all interested parties, according to principle of “homophily” [1].

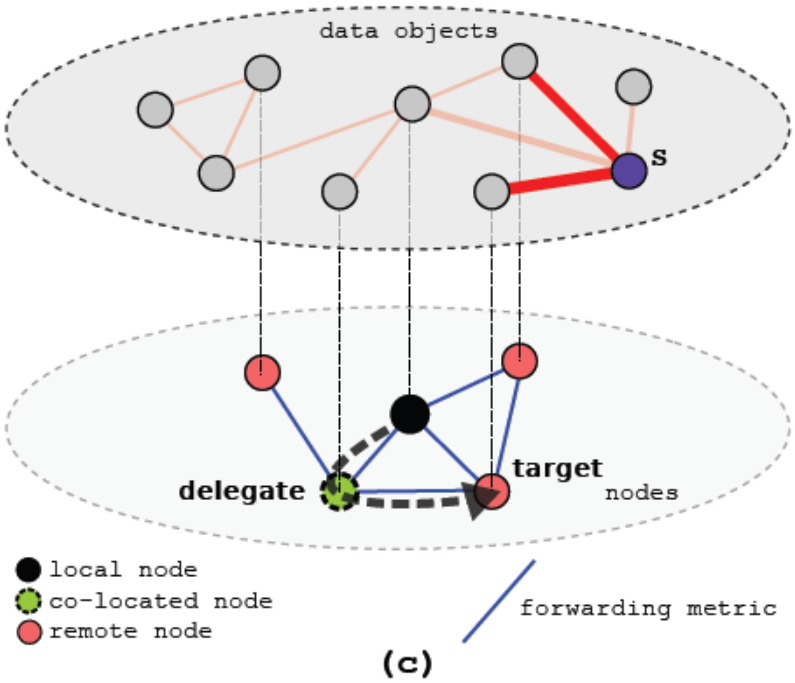
1. McPherson et al “Birds of a Feather: Homophily in Social Networks”

Search-based Resolution

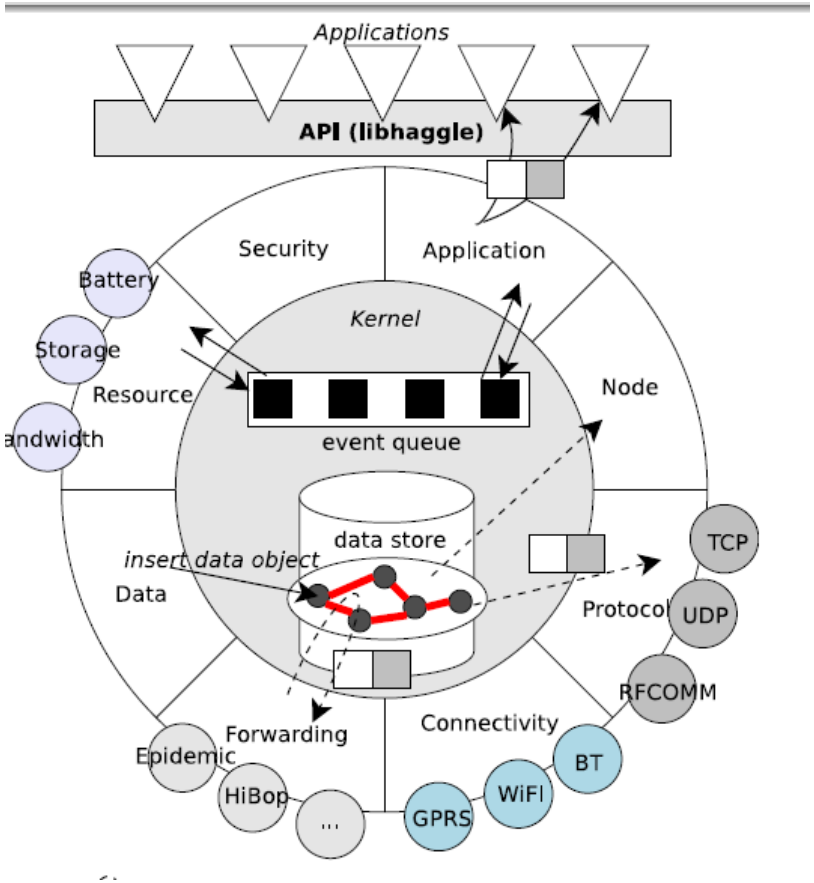


Forwarding

- ***Interest Forwarding***: Resolution pushes top ranked matching data to co-located nodes (and Bloom filters ensure these objects aren't pushed back)
- ***Delegate Forwarding***: Data may be pushed to delegates for future forwarding to other interested nodes. Thus, discovered nodes are also related by a forwarding graph.



Haggle Architecture



- Event-driven kernel, which works well with pub/sub approach
- Managers can form filtered views on the data store
- Many managers provide interfaces for custom modules

Event Model

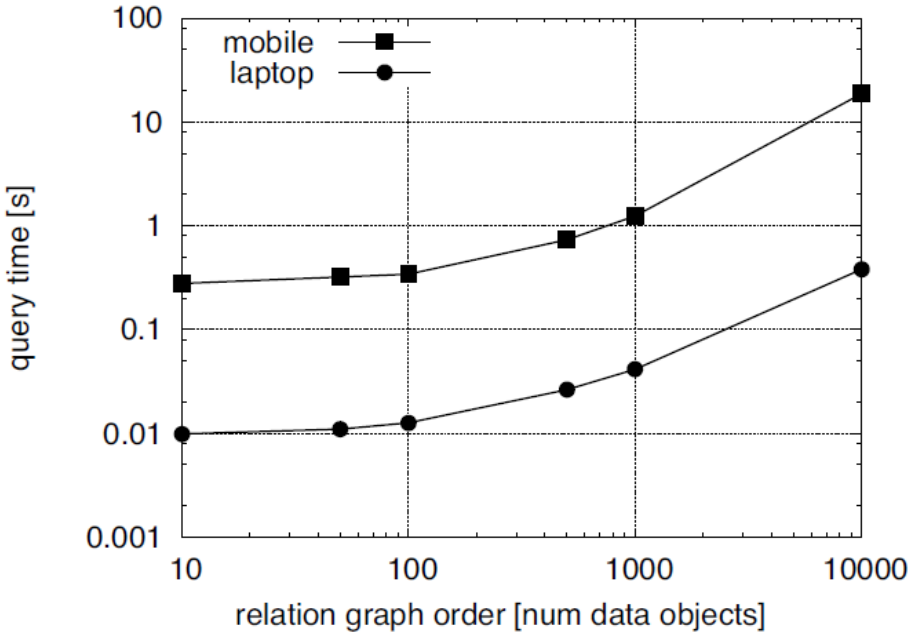
- The API defines various events, that can be private, public or “callback” in nature.
- Public events are generated by the engine, whereas private / callbacks are generated by the managers

Event	Producers	Consumers	Data
Received Data Object	Protocol	Security, Any	Data object
Verified Data Object	Security	Data, Any	Data object
New Data Object	Data	Any	Data object
Local Interface Up	Connectivity	Protocol	Interface
Local Interface Down	Connectivity	Protocol	Interface
New Contact	Node	Forwarding	Node
End of Contact	Node	Forwarding	Node
Send Data Object	Any	Protocol	Data object
Resource Policy	Resource	Any	Policy
Data Object Targets	Data Store	Forwarding	Data object

Table 1: Example public event types, with producers, consumers and associated data.

Evaluation – Resolution Scalability

- Query resolution with many data objects could be time consuming
- Evaluation found that scalability was acceptable, with around 1000 objects
- However, this will also depend on number of interests being matched, etc.



Evaluation – Battery life

- Continuous resolution expends processing power on the mobile device for extended periods
- Since battery life on mobile devices is limited, the impact needs to be minimised
- Results show that Wifi on “battery saving” mode outperforms BlueTooth, but with reduced performance

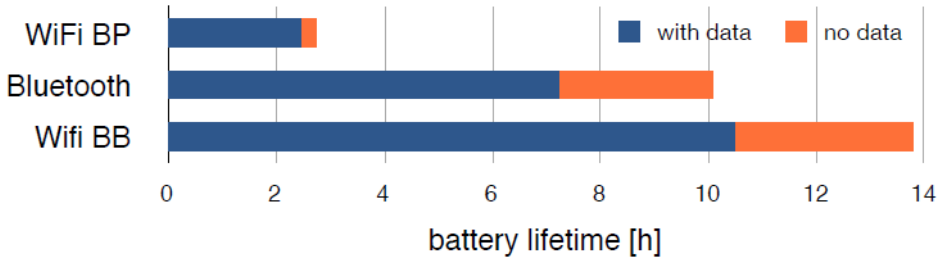
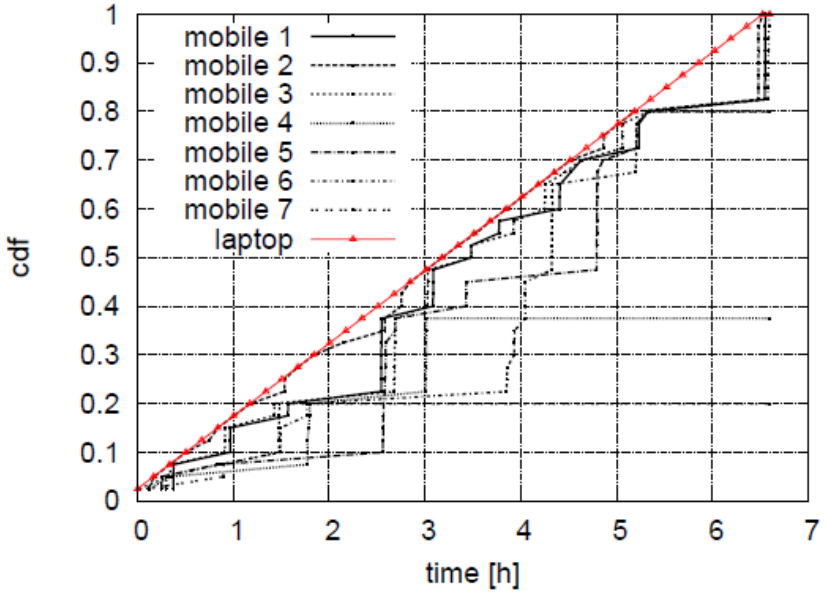
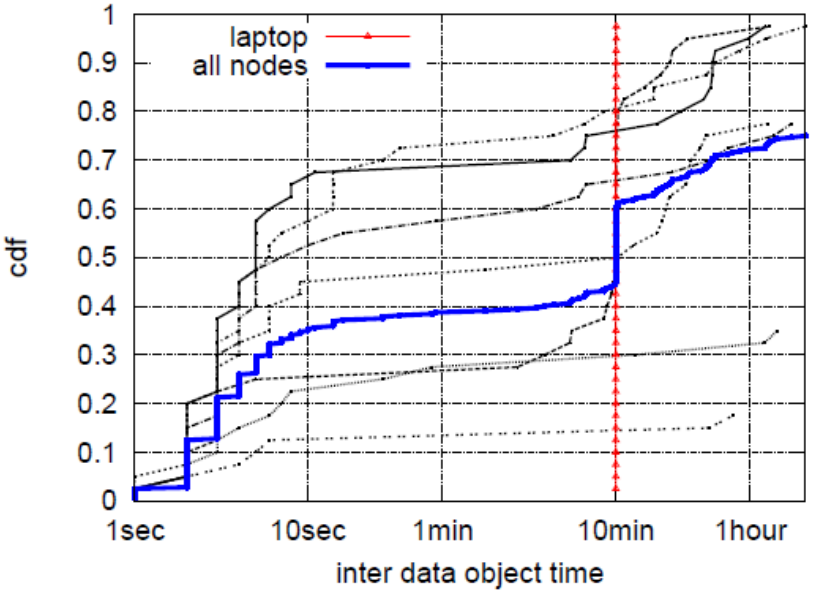


Figure 9: Battery lifetime of the HTC Touch Diamond.

Evaluation – “Live”

- PhotoShare application distributed to seven mobiles and a laptop
- Devices used in “standard office day” pattern
- Search resolution limited to 80 +/- 60s





Overall Impressions

- Provides robust runtime environment to allow rapid development of delay-tolerant applications
- Allows extensibility through custom modules for protocols, forwarding, etc.
- Search-based forwarding appears to be a good fit with opportunistic networking

- Evaluation did not exercise many parameters, e.g.
  - Metadata structure
  - Usage patterns
  - Device/battery types
- No comparison with other systems (or even prior system!)
- Is it possible to achieve more synergy between resolution and delgated forwarding?

Questions / Comments?