Optimal Data Partitioning and Forwarding in Opportunistic Mobile Networks

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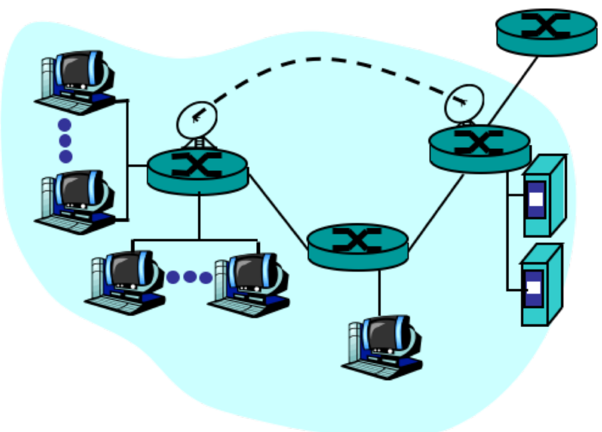
Agenda

- Introduction
  - Current network trends
  - New opportunities in wireless communication
- Routing Design
  - Related Works
  - Cooperative forwarding
- Experiments
- Conclusion and future works

Current Network Environment

- From Internet to Internet of Things
  - ➢ Powerful computation, sensing, and communication abilities
    - ❖ Smartphones, vehicles, wearable devices, etc.
  - ➢ Wide availability of (various) devices
    - ❖ 8 billions of mobile-ready devices, 10 times of PCs [Cisco White Paper]

Internet of things, pervasive computing, Ubiquitous computing, edge computing, etc.



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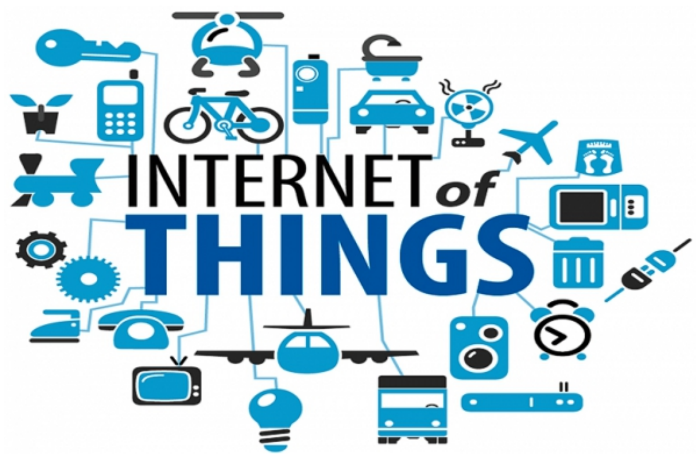

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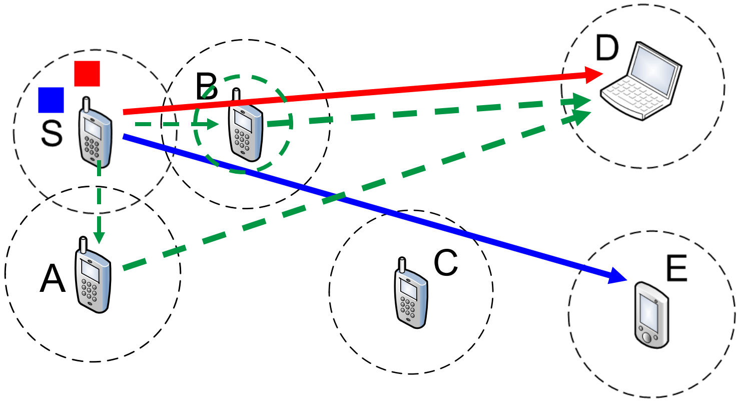
Opportunistic Communication

- Store-Carry-Forward (Mobility)
  - ➢ Mobile nodes physically carry data as relays
  - ➢ Forwarding data upon contacts
    - ❖ Forwarding path: path S-B-D and path A-C-E



  - ➢ **Delay-tolerant (location-based) applications:**
    - ❖ Emails, news, advertisements dissemination
    - ❖ Social networks updates

Opportunistic networks

- Applications
  - Opportunistic mobile social networks
    - Data offloading, disaster communication
  - Vehicular networks
    - Autonomous Driving, intelligence transportation system

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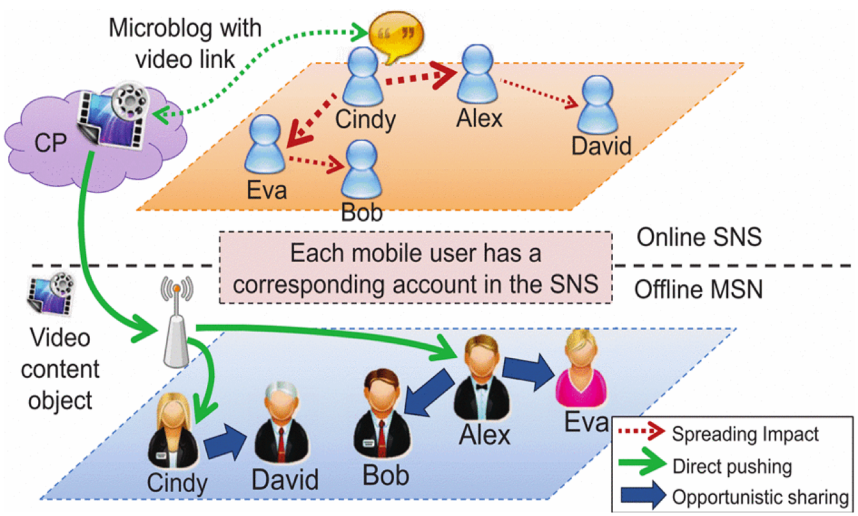


Mobile social networks

Vehicular networks

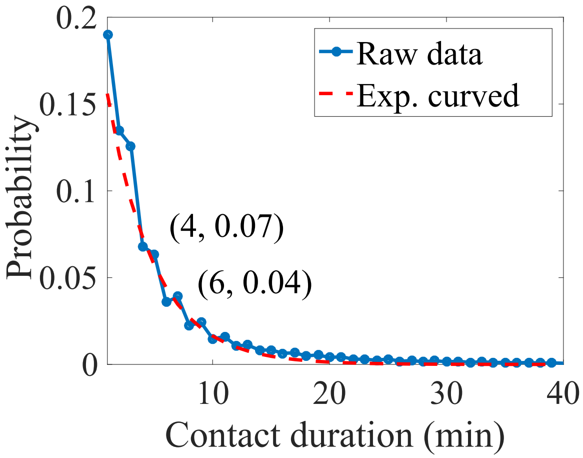
Related Works

- Epidemic
  - Every node can forward data to every one
  - 2-hop extension: only the data source can copy to others
- Delegation forwarding
  - The relay forwards the message to an encounter with a higher quality than those in all previous nodes seen so far.

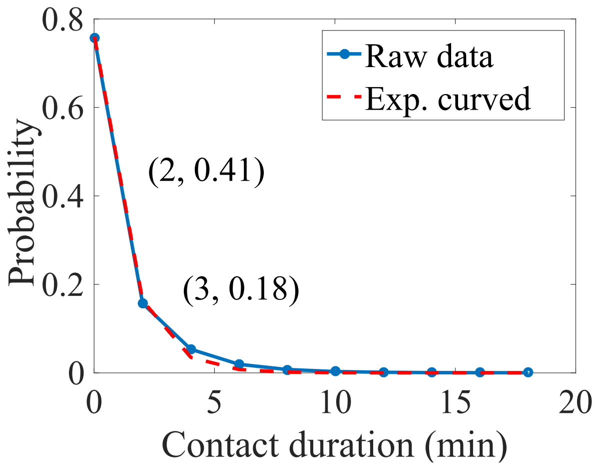
Algorithm	delay	Cost (n)	Knowledge
Epidemic	Minimum	N	No
2-hop extension	Moderate	N/2	No
Delegation	Compared to Epidemic	$\sqrt{N}$	Yes

Cooperative Data Forwarding

- Can the data always be fully transferred in a contact (a common assumption)?
  - ➢ Not always! We verified through two human traces.



INFOCOM trace



SIGCOMM trace

- Observation:
  - ➢ Longer contacts are just a few while short contacts are many.
  - ➢ The contact duration distribution fits the exponential distribution.

Cooperative Data Forwarding

- A better contact model:
  - Delivery probability is not a constant value, P.
  - We model the delivery probability of a node as

$$P(s) = \underline{p}\beta(s),$$

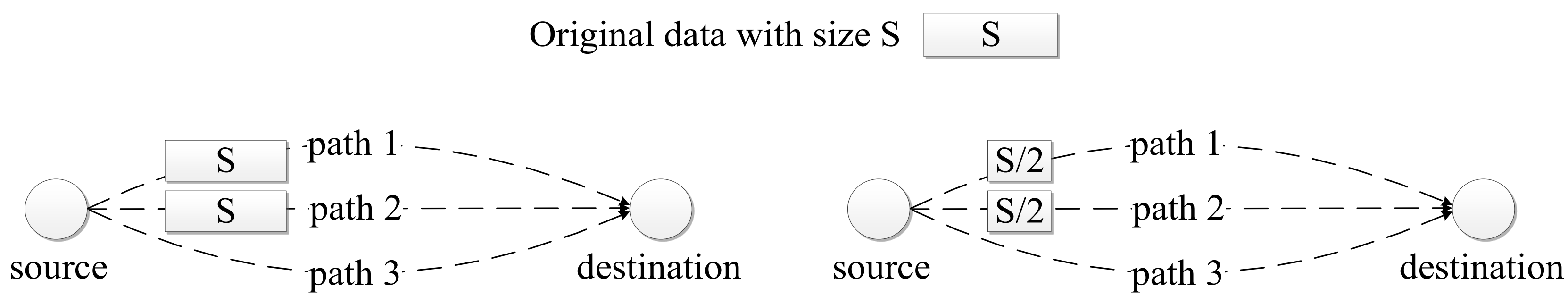
All contact opportunities

where $\beta(s)$ is a non-increasing decay function with data size, s.

- Cooperative forwarding:
  - Partition original data into small data chunks!
  - Cooperative forwarding: maximally improve the probability of data delivery by sending data segments through multiple paths
    - Forwarding path: a sequence of contact

Cooperative Data Forwarding

- Distinguish with replication-based routing
  - ➢ All previous algorithms (e.g., Epidemic, 2-hop, Delegation forwarding routing).



Replication-based routing
- Success: Data in **any** path is delivered;
- Data size: original data size.

Cooperative-based routing
- Success: Data in **every** path is delivered.
- Data size: small data chunk

Cooperative Data Forwarding

- A motivation example
  - The expected delivery probability of different strategies:
    - ❖ Single path routing

      P = 0.22
    - ❖ With one replication

      P = 1 – (1 – 0.22) (1 – 0.22) = 0.39
    - ❖ Split to 2 data chunks

      P = 0.67*0.67 = 0.45
    - ❖ Split to 3 data chunks

      p = 0.74*0.74*0.74 = 0.41

Data size	S	S/2	S/3
Probability	0.22	0.67	0.74

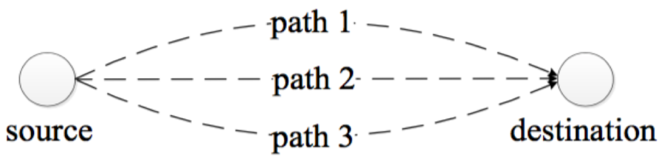


Fig. 2. An illustration of trade-off in the data partitioning.

Cooperative Data Forwarding

- Cooperative Data Forwarding
  - How to determine the optimal partition
    - Good: higher delivery probability for each small data chunk
    - Bad: need to receive data from multiple forwarding paths

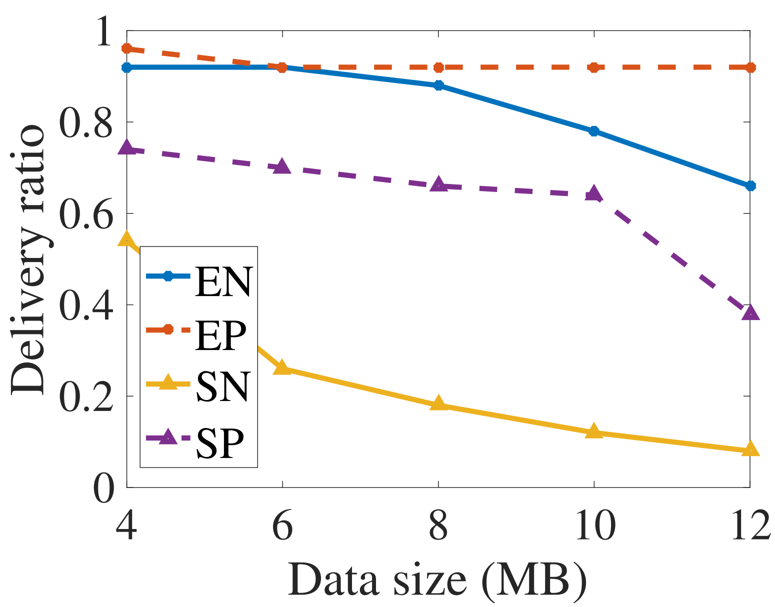
Theory: To maximize data delivery probability if nodes' mobility follows the random-waypoint model and β(s) is a decreasing function, the optimal data-partitioning strategy within deadline T in the epidemic routing is: $s = -p\,\frac{d\beta(s)}{ds}T$

  - Algorithm
    - Calculate the optimal chunk size $s = -\bar{p}\frac{d\beta(s)}{ds}T$
    - if there exists some chunks that the encountered node does not have
      - Replicate data chunk in a round-robin fashion.

Cooperative Data Forwarding

- Cooperative Data Forwarding

	Epidemic	Single-copy probability-based
With partition	EP	SP
Without partition	EN	SN



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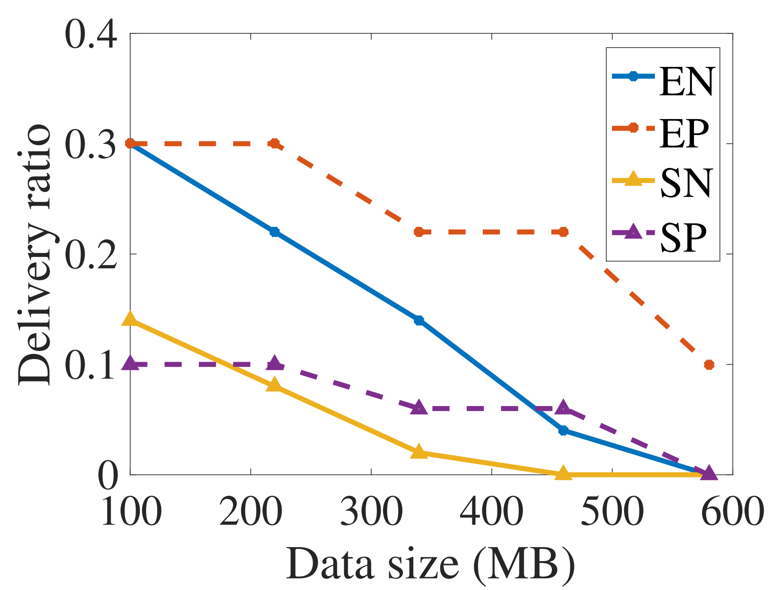
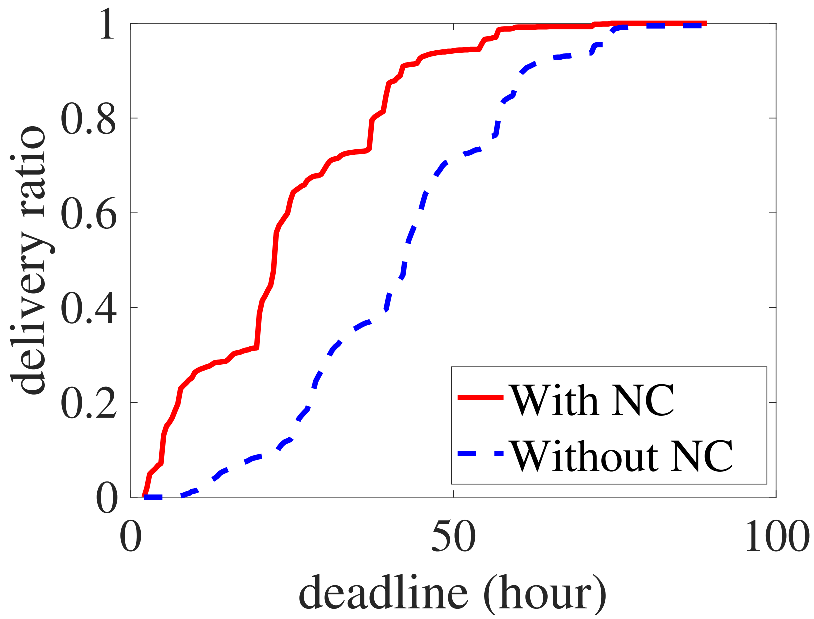


SIGCOMM trace

Cooperative Data Forwarding

- Extension
  - Disadvantage: if one of the data chunk is missed, the data forwarding fails.
  - Solution: network coding technique!



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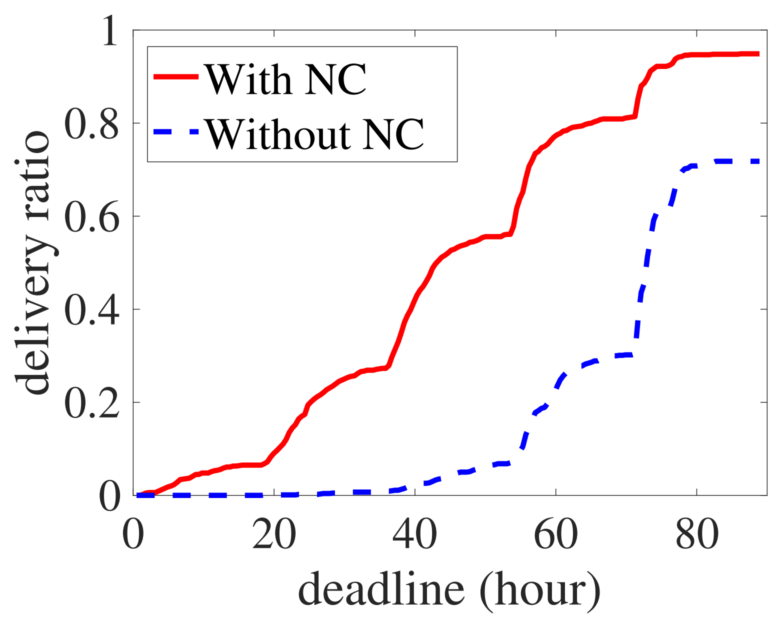

SIGCOMM trace

Conclusion and Future Work

- Opportunistic networks
  - There are many opportunistic contacts in IoT environment
  - Opportunistic communication (Store-Carry-Forward)
- Routing methods
  - The contact duration might be insufficient for data transmission
    - Cooperative Data Forwarding
  - Verified through two human traces
- Future works
  - Try more data traces, e.g, vehicular traces.
  - Try to use network knowledge to optimize routing performance.

Thank you!

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