Anonymous DTN routing

September 12, 2013

1 Experimental Result

1.1 Overview

1.1.1 Simulation model

- ONE simulator, modified default scenario/setting
- Map: Helsinki (4500m * 3500m)
- Simulation running time: 12 hours
- Nodes: 246 (160 humans, 80 cars, 6 trams)
  - Packet buffer: Humans and cars (50MB), trams (500MB).
  - Contact interval: Humans (2 mins 30 secs), cars (1 min), trams (40 secs)
- Packet(message) generation
  - Packet size: 500KB - 1MB
  - Packet generation interval: 35sec - 50sec
  - TTL: 5 hours
  - Packet generation stopped when 5 hours (packet TTL) are left.
  - Total number of packets generated: about 575
- Movement: Random way point, map-based movement.
- Network interface: bluetooth, wlan (determine communication distance and bandwidth)
  - Humans, cars: Bluetooth (Bandwidth: 2Mbps, Communication range: 10m)
  - Trams: WLAN (Bandwidth: 10Mbps, Communication range: 100m)

1.1.2 Anonymous DTN routing setup

- # group: 1
- # nodes in a group: [5%, 10%, 15%, 20%, 25%]
- Epoch: [10mins, 20mins, 30mins, 60mins]
- Ephemeral ID duration: [3 epochs, 6 epochs]
- Base routing protocol: epidemic (flooding)

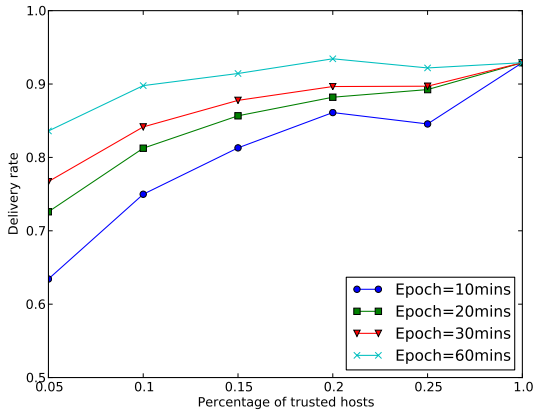
1.1.3 Assumptions & simplification

- Communication within a group
  Only nodes belong to any "group" can send packets to other nodes it trusts. Nodes that don't belong to any group cannot generate packets.
- Strict time sync
  Epoch starts exactly at the same time in all nodes
- No "beacon", "hello", "pull" messages
  Once two nodes are located within a specific distance, they know ephemeral addresses, packet digest, pulling list of each other without any message exchange.
- Forwarding policy
  On contact, a node first forwards packets whose destinations are either trusted by the next-hop node or in neighbor list of the next-hop node. Then it tries to forward remaining packets in FIFO manner.

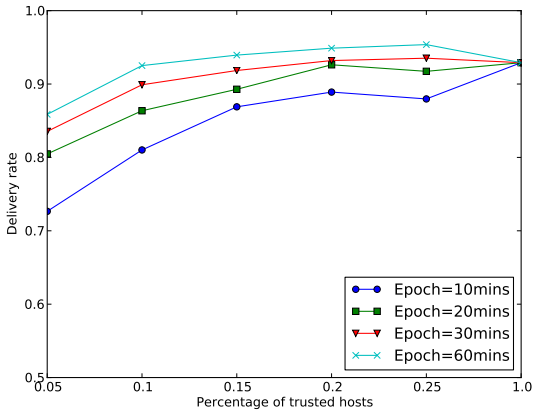
1.2 Results

Ephemeral ID duration	Trusted nodes %	Epoch
3 epochs	10%	60 mins
6 epochs	10%	30 mins
	20%	20 mins

Table 1: **Example settings with delivery rate of about 90% (Flooding: 92.91%).**

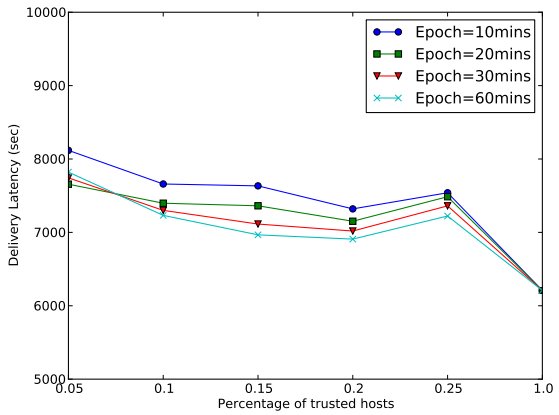


(a) Delivery rate: Ephemeral ID valid for 3 epochs

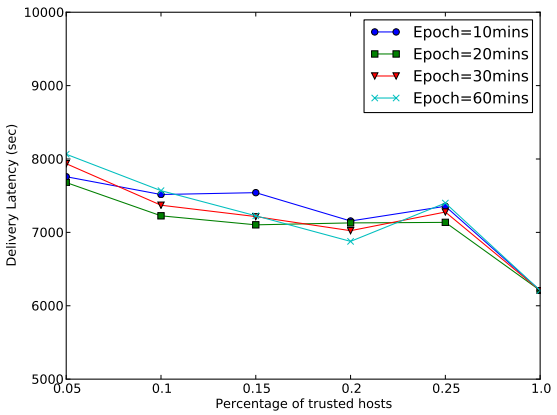


(b) Delivery rate: Ephemeral ID valid for 6 epochs

Figure 1: **Packet delivery rate.** Delivery rate of pure epidemic routing protocol: 92.91%. Increasing ephemeral ID duration from 3 epochs to 6 epochs enhances the delivery rate significantly.

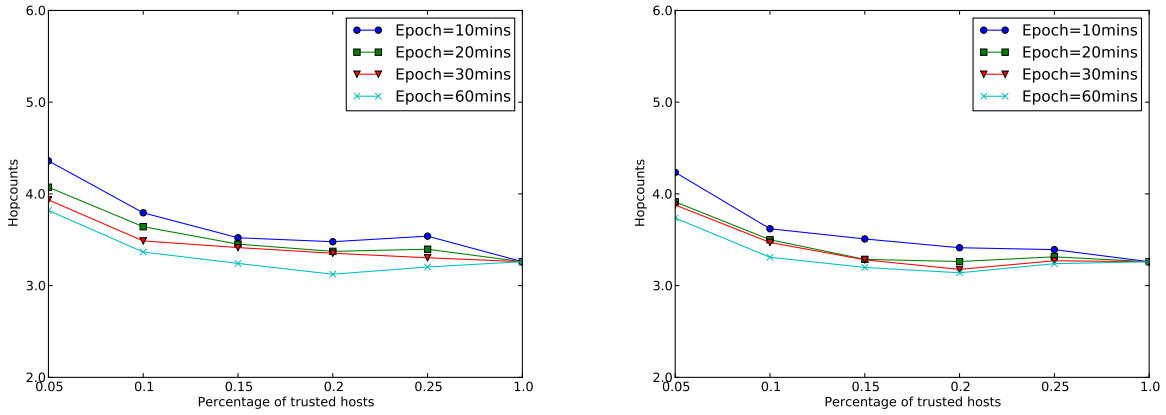


(a) Delivery latency: Ephemeral ID valid for 3 epoch



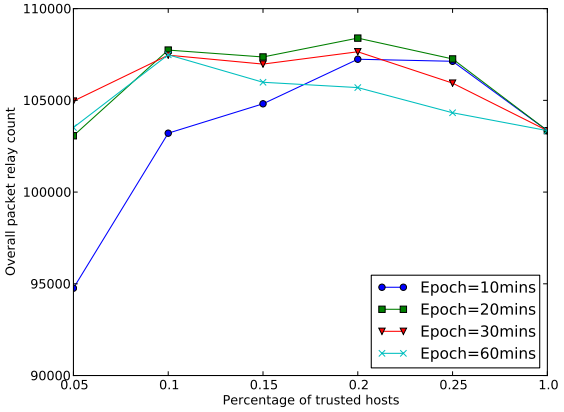
(b) Delivery latency: Ephemeral ID valid for 6 epochs

Figure 2: **Packet delivery latency.** In every case, delivery latency of our protocol is 1000 - 2000 secs longer than that of flooding protocol.

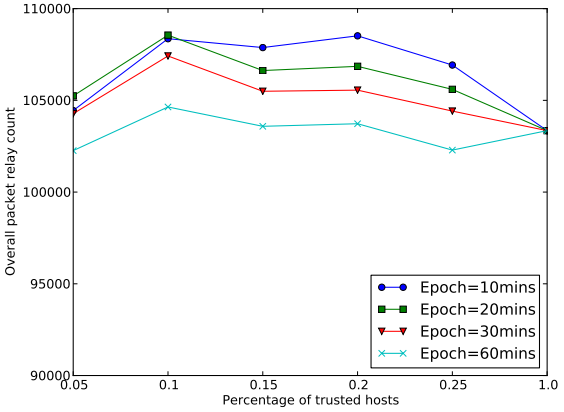


(a) Delivery hop count: Ephemeral ID valid for 3 epochs (b) Delivery hop count: Ephemeral ID valid for 6 epochs

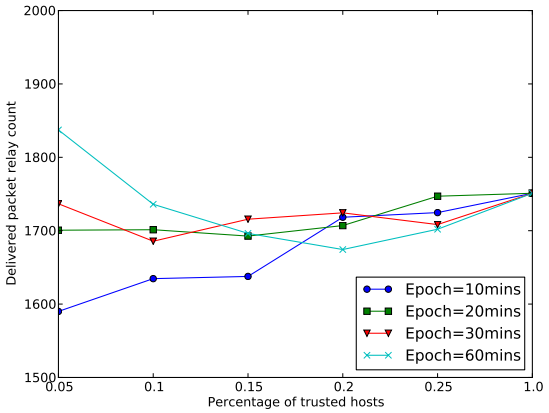
Figure 3: **Packet delivery hop count.** In general, delivery hop count is increased by less than 1 hop.



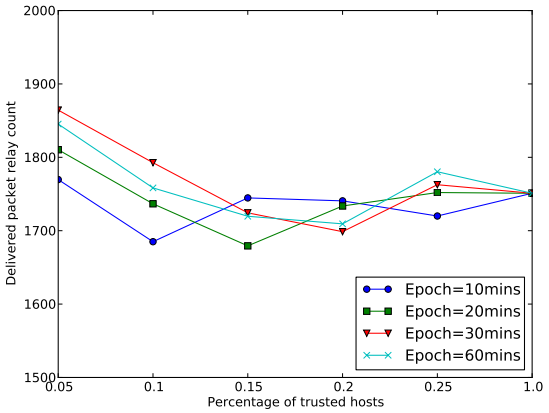
(a) Relay count of overall packets. Ephemeral ID valid for 3 epochs.



(b) Relay count of overall packets. Ephemeral ID valid for 6 epochs.

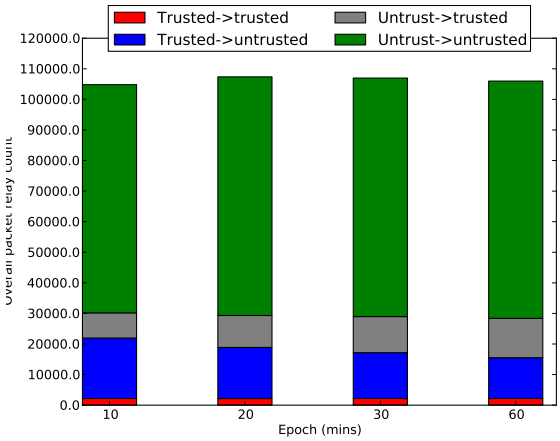


(c) Relay count of delivered packets only. Ephemeral ID valid for 3 epochs.

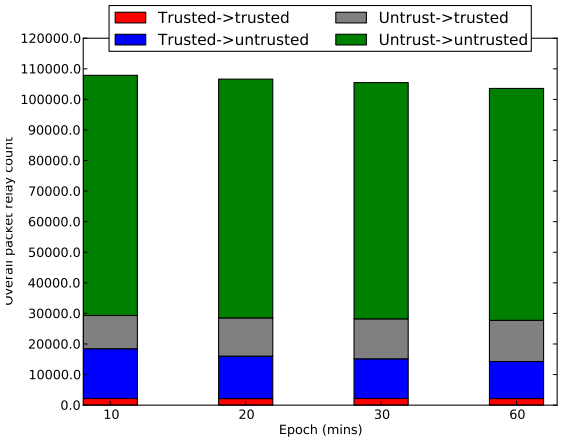


(d) Relay count of delivered packets only. Ephemeral ID valid for 6 epochs.

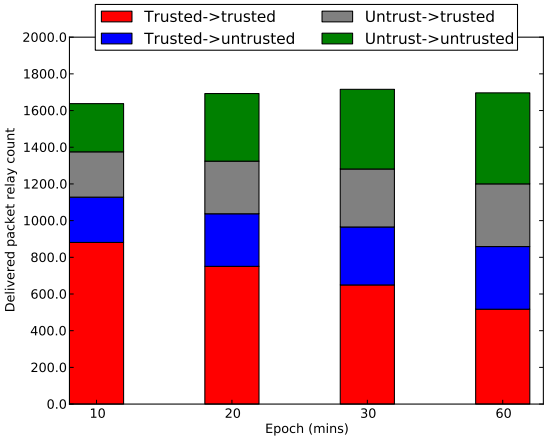
Figure 4: **Packet relay count.** Only about 2% of packet relays are used for actual packet deliveries.



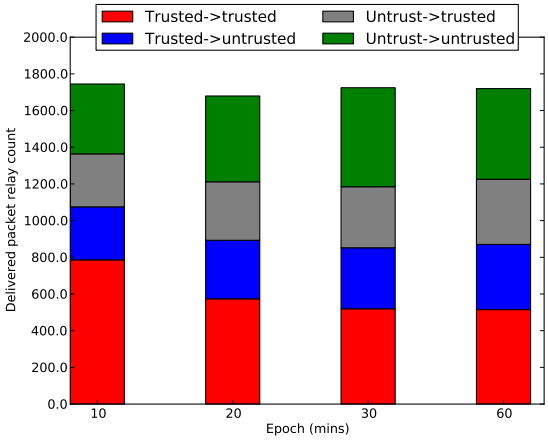
(a) Overall packet relay classification. Ephemeral ID valid for 3 epochs



(b) Overall packet relay classification. Ephemeral ID valid for 6 epochs

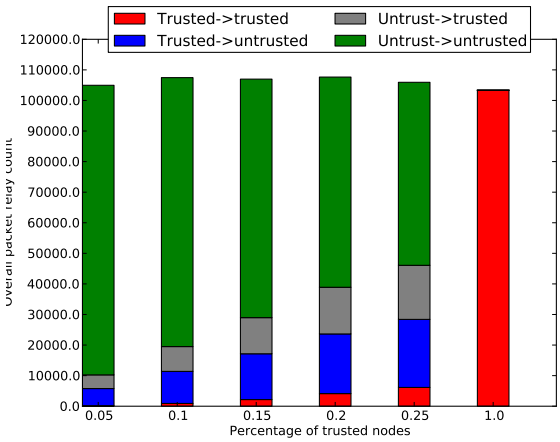


(c) Delivered packet relay classification. Ephemeral ID valid for 3 epochs

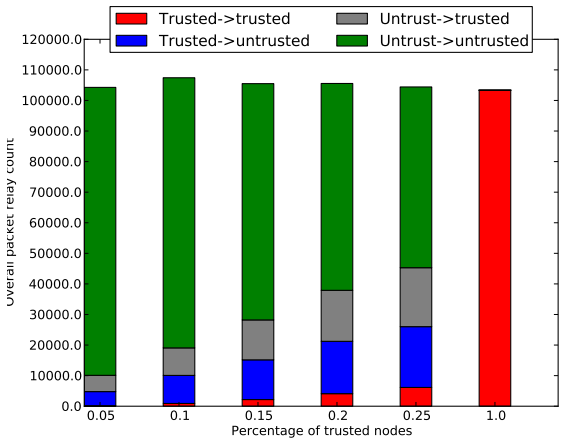


(d) Delivered packet relay classification. Ephemeral ID valid for 6 epochs

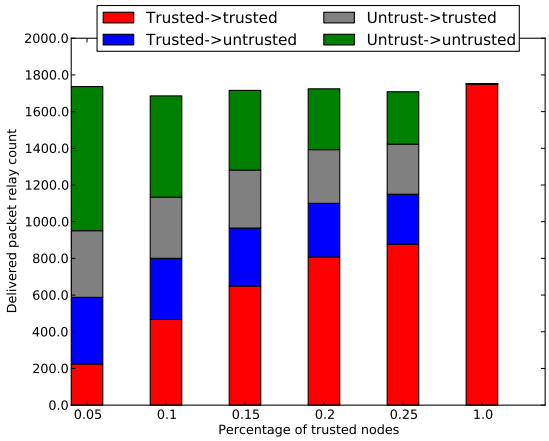
Figure 5: **Packet relay classification over varying epoch. Percentage of trusted nodes is** 15%**.** Ephemeral ID duration does not affect overall packet relay classification, but it affects delivered packet relay classification. When ephemeral ID duration is 6 epochs, packet relays between two trusted nodes are slightly decreased while other types of relays are increased.



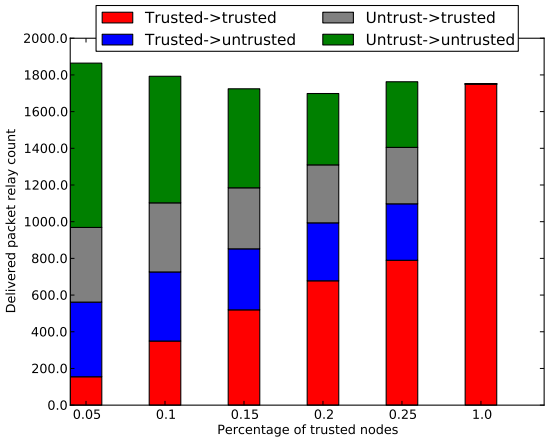
(a) Overall packet relay classification. Ephemeral ID valid for 3 epochs.



(b) Overall packet relay classification. Ephemeral ID valid for 6 epochs.

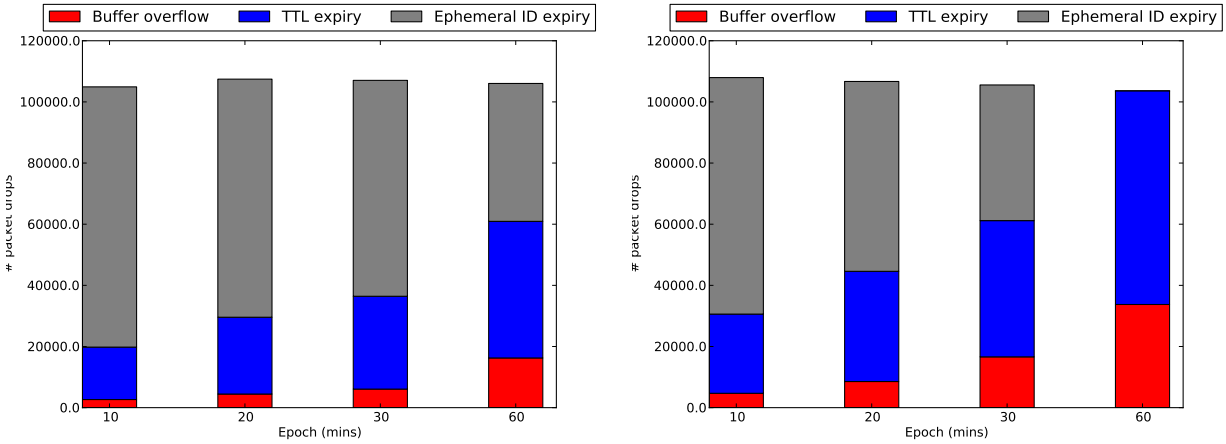


(c) Delivered packet relay classification. Ephemeral ID valid for 3 epochs.



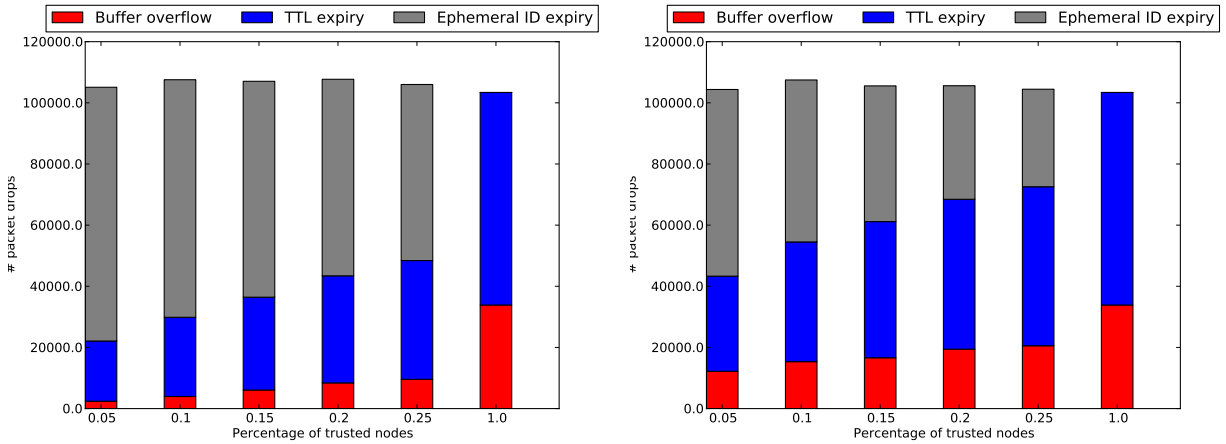
(d) Delivered packet relay classification. Ephemeral ID valid for 6 epochs.

Figure 6: **Packet relay classification over varying percentage of trusted nodes. Epoch is 30 mins.** As in Figure 5, ephemeral ID duration does not affect overall packet relay classification but affects delivered packet relay classification.



(a) Packet drops over varied epoch. Percentage of trusted nodes = 15%. Ephemeral ID valid for 3 epochs.

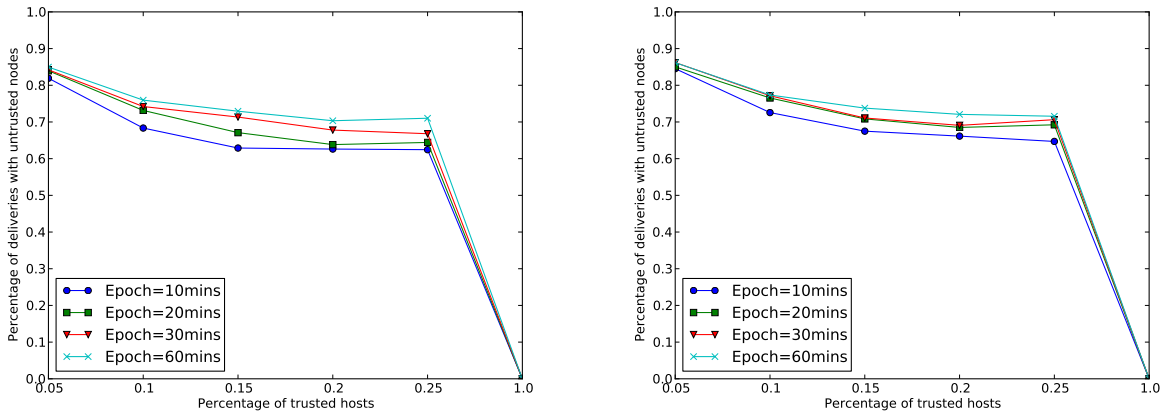
(b) Packet drops over varied epoch. Percentage of trusted nodes = 15%. Ephemeral ID valid for 6 epochs.



(c) Packet drops over varied percentage of trusted nodes. Epoch = 30 mins. Ephemeral ID valid for 3 epochs.

(d) Packet drops over varied percentage of trusted nodes. Epoch = 30 mins. Ephemeral ID valid for 6 epochs.

Figure 7: **Packet drop classification.** With ephemeral ID valid for 6 epochs (Figures 7b and 7d), packet drops due to ephemeral ID expiry are decreased significantly.



(a) Packet deliveries with untrusted nodes: Ephemeral ID valid for 3 epochs.

(b) Packet deliveries with untrusted nodes: Ephemeral ID valid for 6 epochs.

Figure 8: **Packet deliveries with untrusted nodes.**