Anonymous DTN routing

September 6, 2013

1 Experimental Result

1.1 Overview

1.1.1 Simulation model

- ONE simulator, default scenario/setting
- Map: Helsinki (4500m * 3500m)
- Nodes: 246 (160 humans, 80 cars, 6 trams)
  - Packet buffer: Humans and cars (50MB), trams (500MB).
  - Contact interval: Humans (mins), cars (mins), trams (min secs)
- Packet(message) generation
  - Packet size: 500KB - 1MB
  - Packet generation interval: 35sec - 50sec
  - TTL: 5 hours
- 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)
- Simulation running time: 12 hours

1.1.2 Anonymous DTN routing setup

- # group: 1
- # nodes in a group: varies from 5% to 30%
- Epoch: varies from 10 mins to 60 mins
- Base routing protocol: epidemic (flooding)

1.1.3 Assumptions & simplification

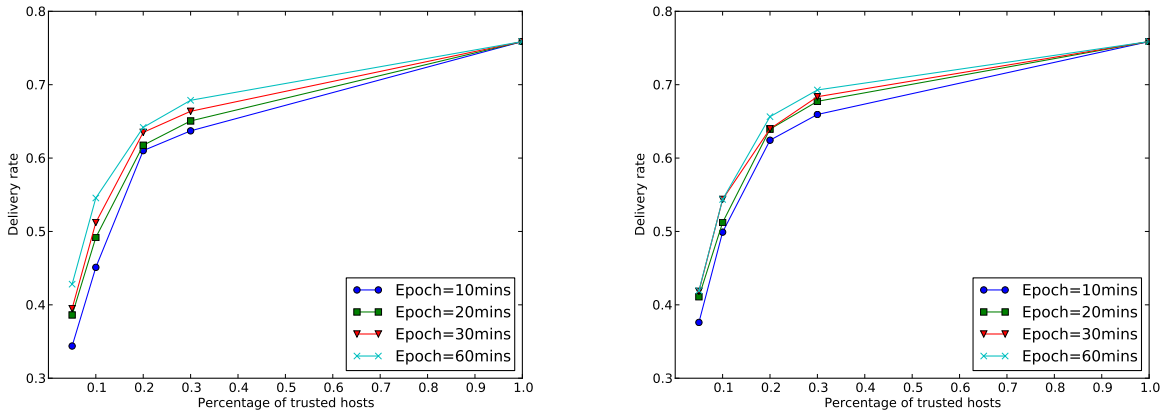
- Communication within a group
  Only nodes belong to any "group" can send packets to other nodes it trusts. Nodes that don't belong to any group cannot generate packets.

- 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.

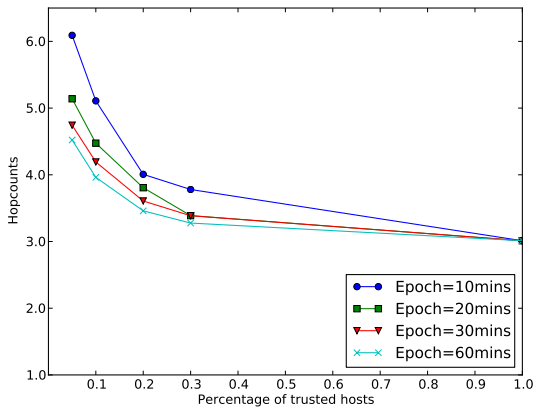
1.2 Results



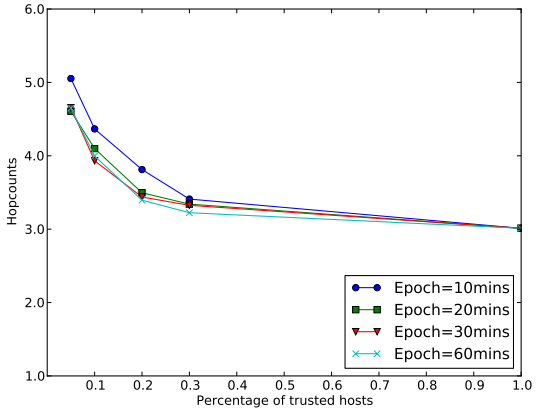
(a) Delivery rate: Ephemeral ID valid for 3 epochs

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

Figure 1: **Packet delivery rate.** Delivery rate of pure epidemic routing protocol: 75.88%. Increasing ephemeral ID duration from 3 epochs to 6 epochs enhances the delivery rate slightly, but not significantly.

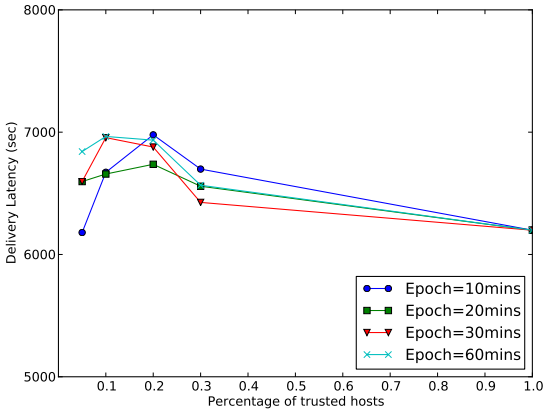


(a) Delivery hop count: Ephemeral ID valid for 3 epochs

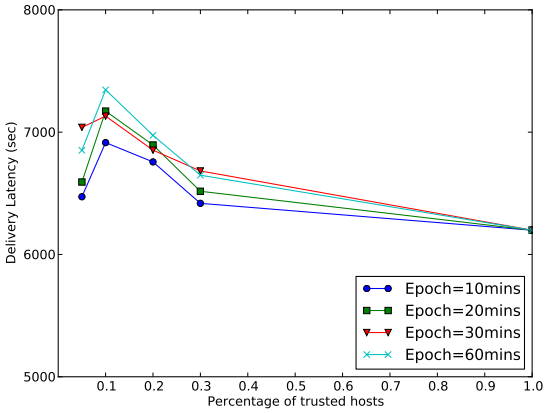


(b) Delivery hop count: Ephemeral ID valid for 6 epochs

Figure 2: **Packet delivery hop count.** Delivery hop count in Figure 2a and 2b are higher than that of pure epidemic routing, especially when the percentage of trusted nodes is low due to inefficient routing using small number of trusted nodes.

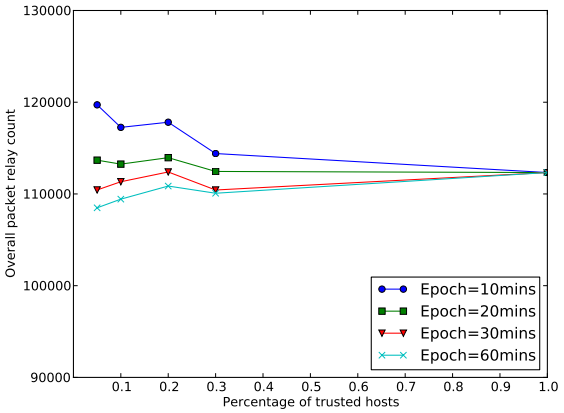


(a) Delivery latency: Ephemeral ID valid for 3 epoch

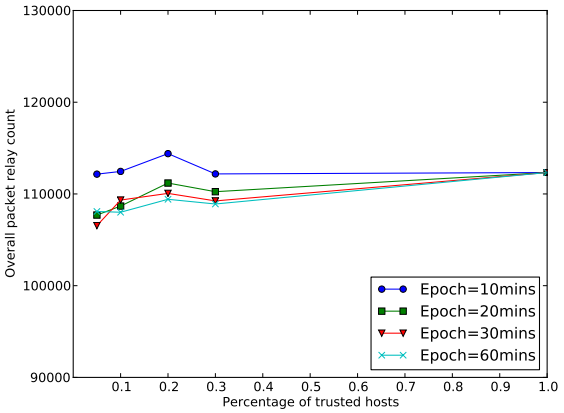


(b) Delivery latency: Ephemeral ID valid for 6 epochs

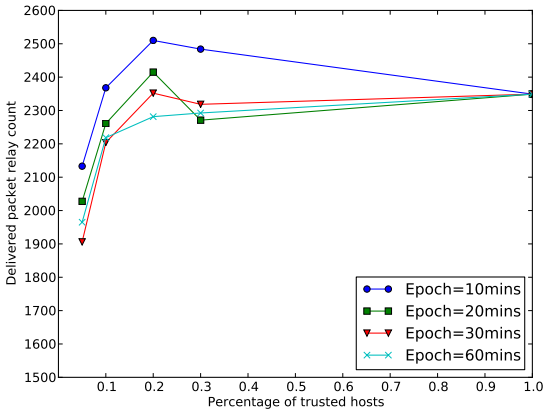
Figure 3: **Packet delivery latency.** Packet delivery latency in Figure 3b is little bit higher than that in Figure 3a, probably because of higher delivery rate.



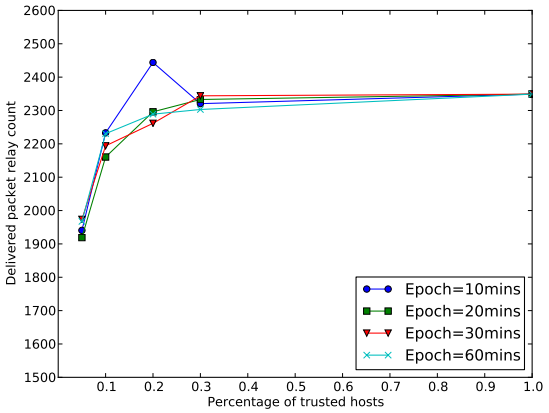
(a) Relay count of overall packets. Ephemeral ID valid for 3 epochs.



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

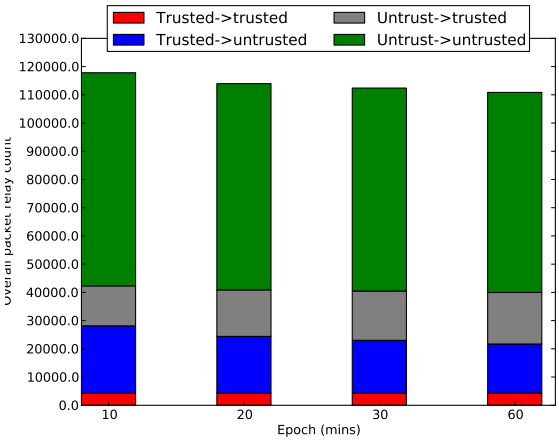


(c) Relay count of delivered packets only. Ephemeral ID valid for 3 epochs.

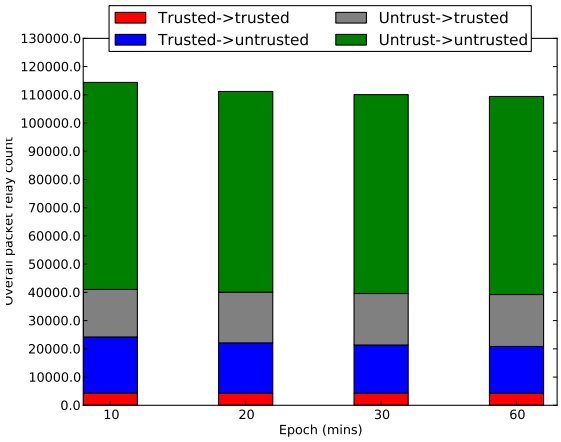


(d) Relay count of delivered packets only. Ephemeral ID valid for 6 epochs.

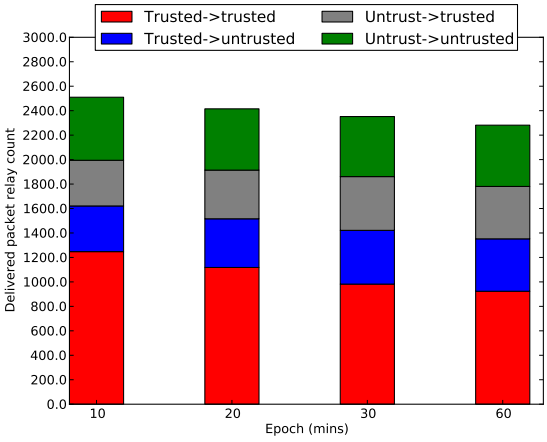
Figure 4: **Packet relay count.** In flood-based routing protocol, only about 5% of packet relays are used for actual packet deliveries. When the percentage of trusted nodes is less than 10%, the number of relays for delivered packets is extremely low.



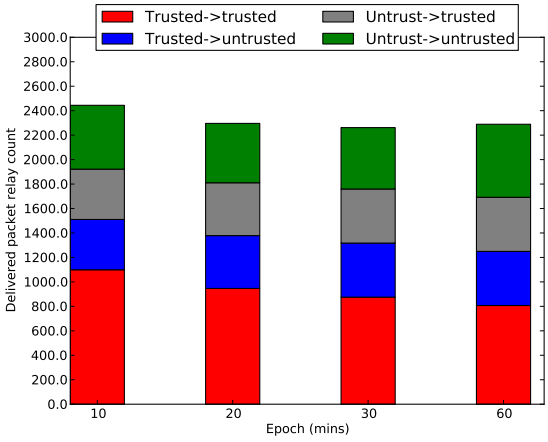
(a) Overall packet relay classification. Ephemeral ID valid for 3 epochs



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

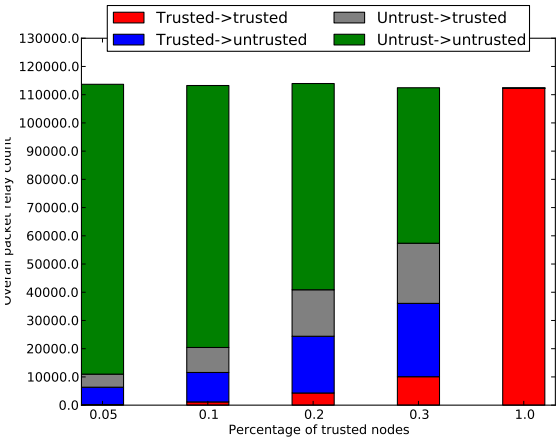


(c) Delivered packet relay classification. Ephemeral ID valid for 3 epochs

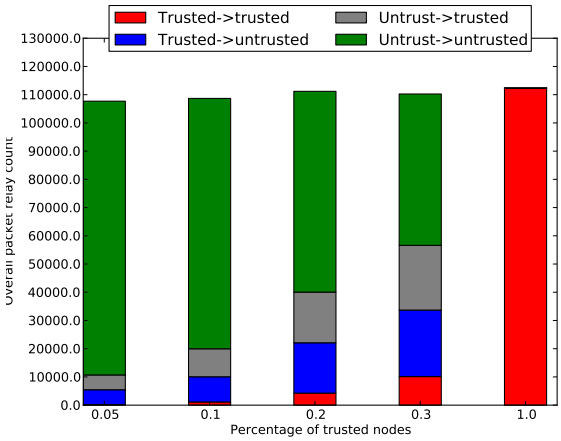


(d) Delivered packet relay classification. Ephemeral ID valid for 6 epochs

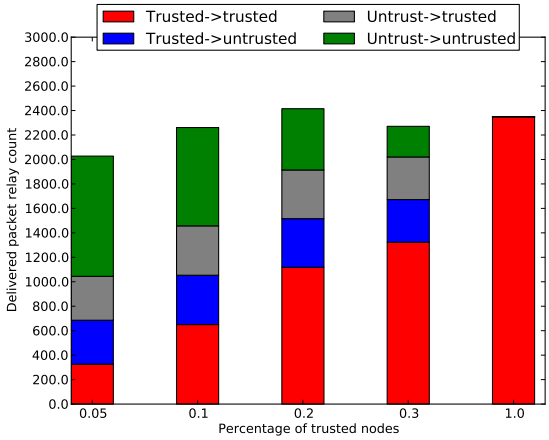
Figure 5: **Packet relay classification over varying epoch. Percentage of trusted nodes is 20%.** Relay classification is not significantly different across different epochs.



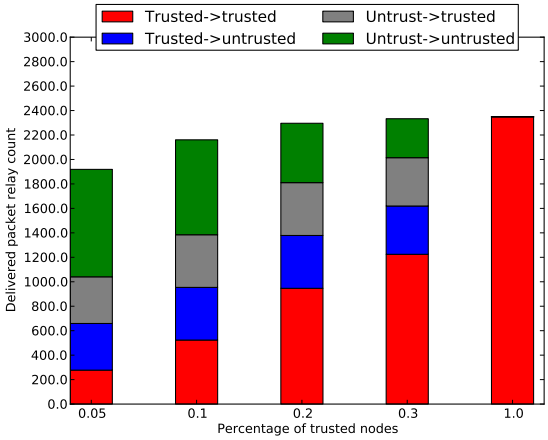
(a) Overall packet relay classification. Ephemeral ID valid for 3 epochs.



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

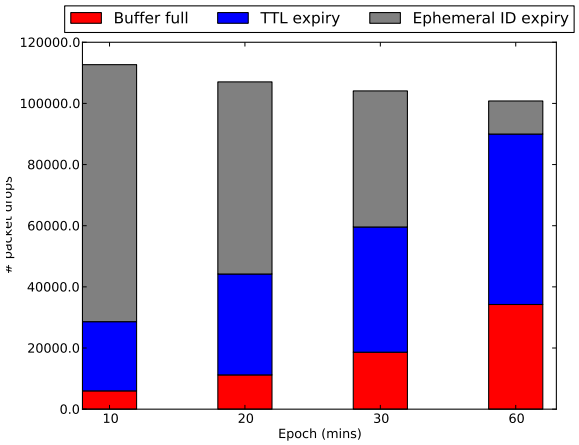


(c) Delivered packet relay classification. Ephemeral ID valid for 3 epochs.

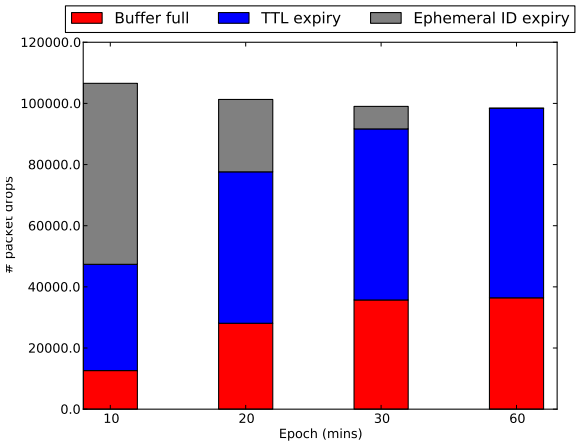


(d) Delivered packet relay classification. Ephemeral ID valid for 6 epochs.

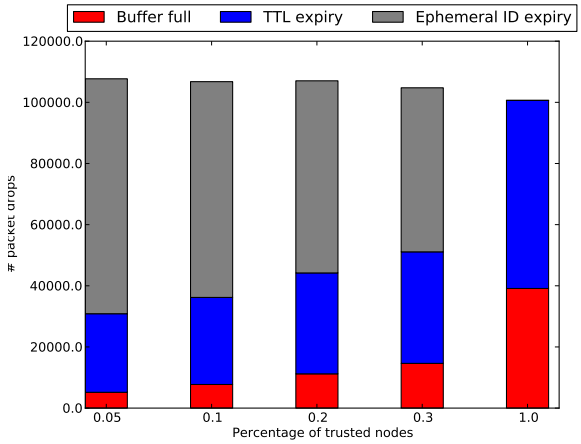
Figure 6: **Packet relay classification over varying percentage of trusted nodes. Epoch is 20 mins.** As in Figure 5, relays between two untrusted nodes account for relatively small part while relays between two trusted nodes account for the largest part (in most cases) in delivered packet relay classification.



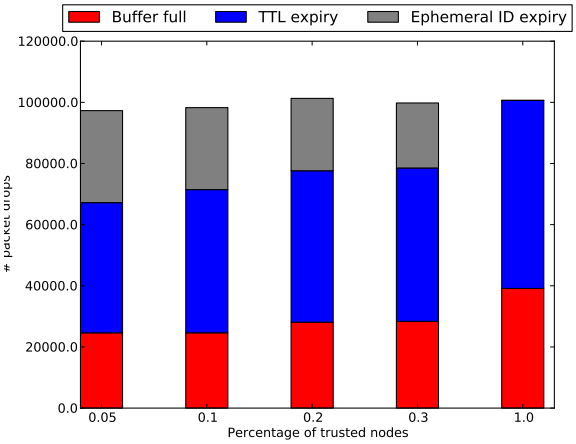
(a) Packet drops over varied epoch. Percentage of trusted nodes = 0.2. Ephemeral ID valid for 3 epochs.



(b) Packet drops over varied epoch. Percentage of trusted nodes = 0.2. Ephemeral ID valid for 6 epochs.

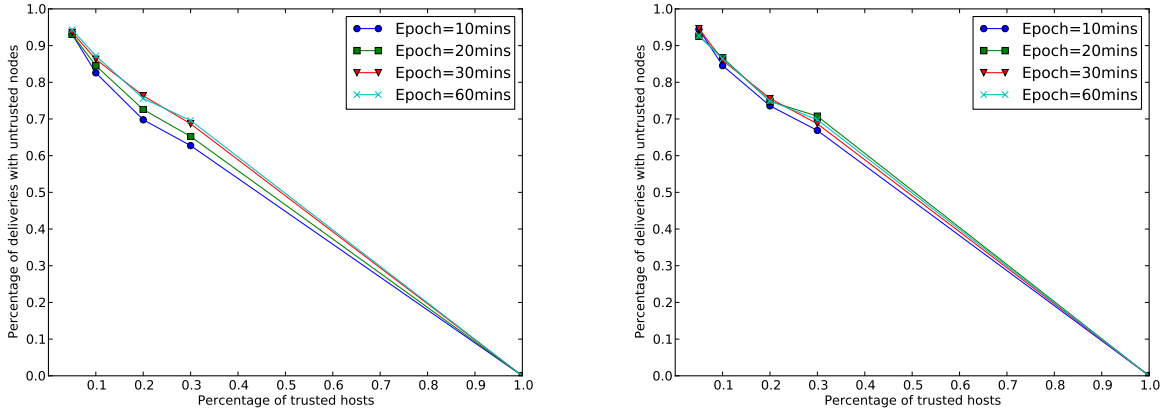


(c) Packet drops over varied percentage of trusted nodes. Epoch = 20 mins. Ephemeral ID valid for 3 epochs.



(d) Packet drops over varied percentage of trusted nodes. Epoch = 20 mins. Ephemeral ID valid for 6 epochs.

Figure 7: **Packet drop classification.** With ephemeral ID valid for 6 epochs (Figures 7b and 7d), the total number of packet drops is slightly decreased compared to when ephemeral ID valid for 3 epochs is used (Figures 7a and 7c), mainly because packet drops due to ephemeral ID expiry is decreased.



(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.**