Anonymous DTN routing

September 4, 2013

1 Experimental Result

1.1 Overview

1.1.1 Simulation model

- ONE simulator, default scenario/setting
- Map: Helsinki (4500m * 3500m)
- Nodes: 126 (80 humans, 40 cars, 6 trams)
  - Packet buffer: Humans and cars (5MB), trams (50MB).
  - Contact interval: Humans (5mins), cars (2mins), trams (1min 20secs)
- Packet(message) generation
  - Packet size: 500KB - 1MB
  - Packet generation interval: 25sec - 35sec
  - TTL: 5 hours
- Movement: Pre-defined routes
- Network interface: bluetooth, wlan (determine communication distance and bandwidth)
- Simulation running time: 12 hours

1.1.2 Anonymous DTN routing setup

- # group: 1
- # nodes in a group: varies from 10% to 100%
- Epoch: varies from 5 mins to 30 mins
- Base routing protocol: epidemic

1.1.3 Assumptions & simplification

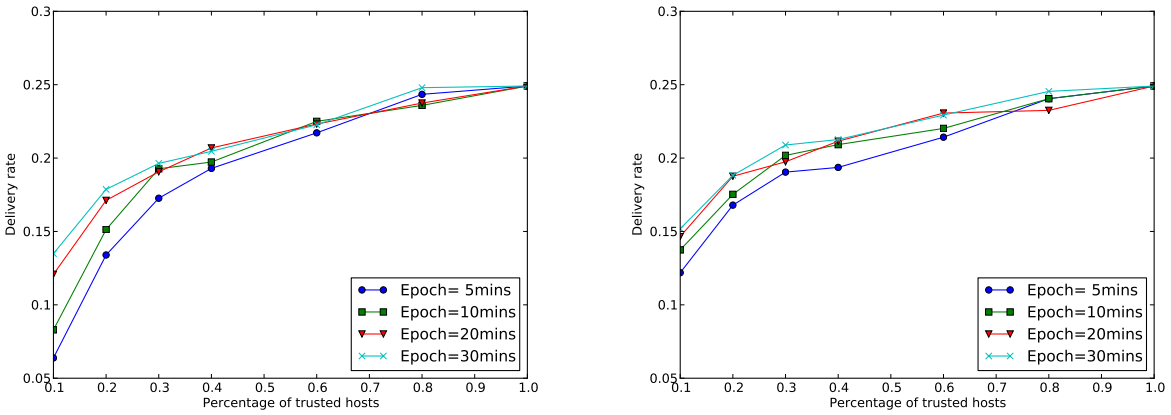
- Communication within a group
  Only nodes belong to any "group" can send packets to other nodes it trusts. Nodes that don't belong to any group cannot generate packets.

- 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.

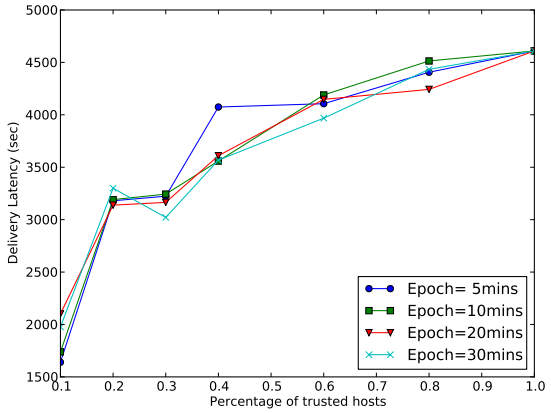
1.2 Results



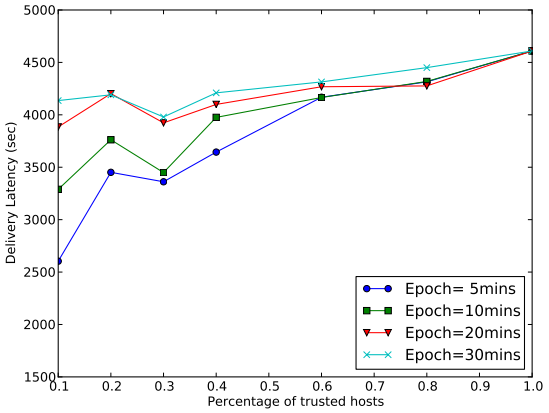
(a) Delivery rate: Ephemeral ID valid for 1 epoch

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

Figure 1: **Packet delivery rate.** Delivery rate with 100% trusted nodes is exactly same to that of pure epidemic routing protocol (Delivery rate of 24.91%). Delivery rate with 30 min epoch in Figure 1a and delivery rate with 10 min epoch in Figure 1b show almost similar result.

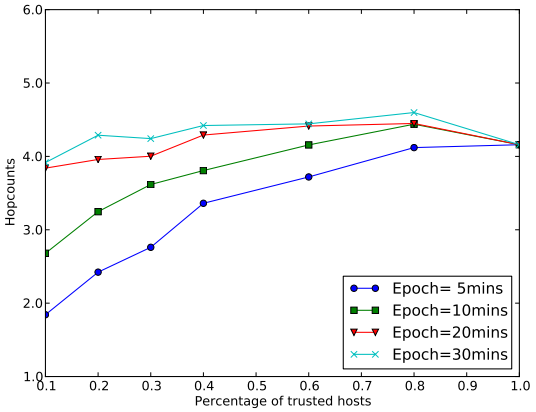


(a) Delivery latency: Ephemeral ID valid for 1 epoch

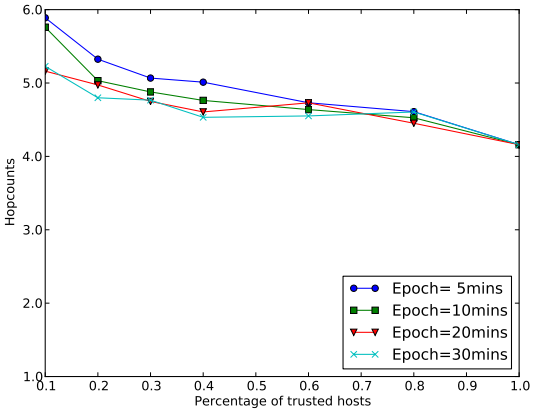


(b) Delivery latency: Ephemeral ID valid for 3 epochs

Figure 2: **Packet delivery latency.** Packet delivery latency in Figure 2b is much higher than in Figure 2a, especially when the percentage of trusted nodes is low.

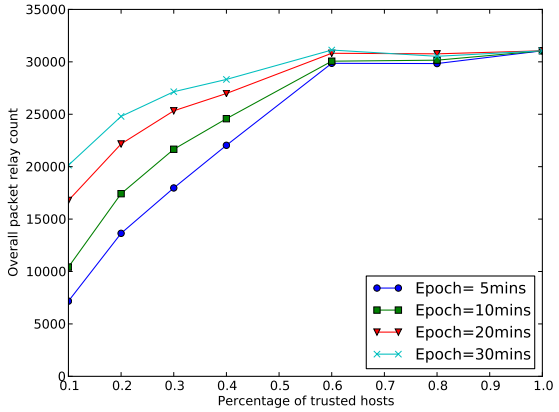


(a) Delivery hop count: Ephemeral ID valid for 1 epoch

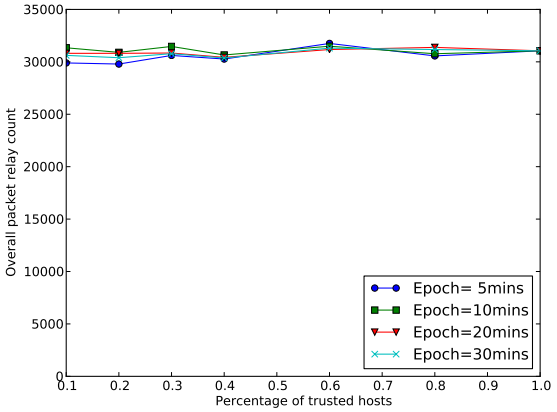


(b) Delivery hop count: Ephemeral ID valid for 3 epochs

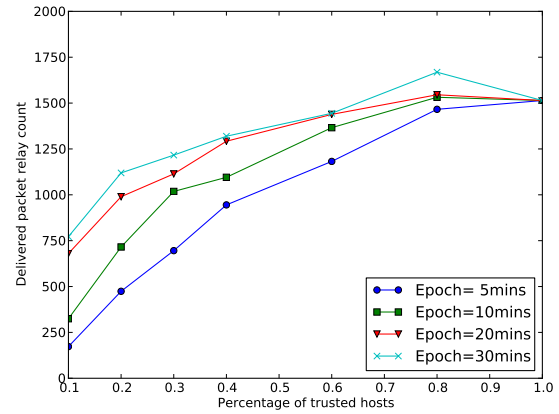
Figure 3: **Packet delivery hop count.** Delivery hop count in Figure 3a is generally lower than that of pure epidemic routing, since packets are dropped due to ephemeral ID expiry. Delivery hop count in Figure 3b is generally higher than that of pure epidemic routing, especially when the percentage of trusted nodes is low due to inefficient routing using small number of trusted nodes.



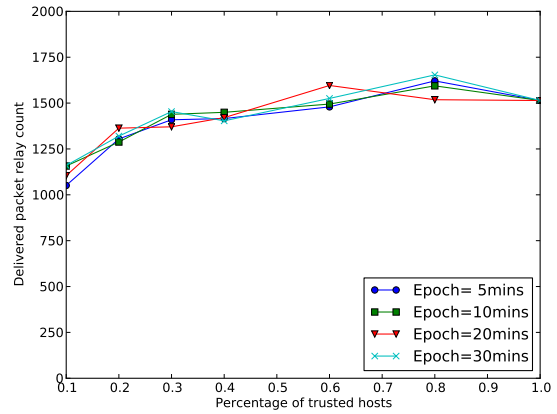
(a) Relay count of overall packets. Ephemeral ID valid for 1 epoch.



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

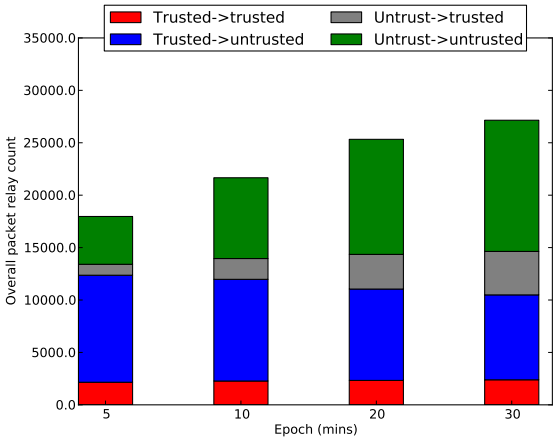


(c) Relay count of delivered packets only. Ephemeral ID valid for 1 epoch.

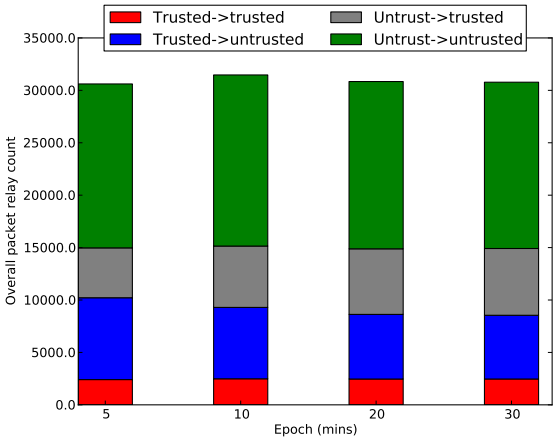


(d) Relay count of delivered packets only. Ephemeral ID valid for 3 epochs.

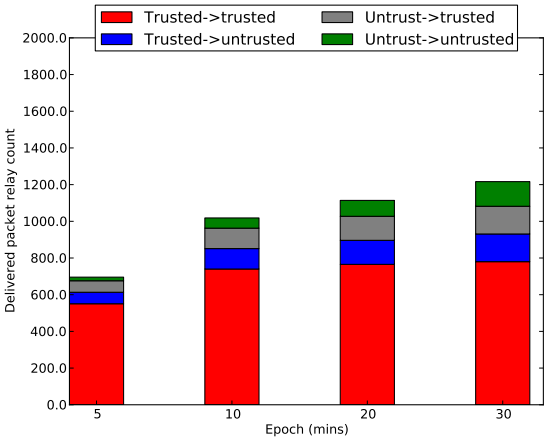
Figure 4: **Packet relay count.** In flood-based routing protocol, only about 5% of packet relays are used for actual packet deliveries. When ephemeral ID valid for 3 epochs is used (Figures 4b and 4d), the number of packet relays (both overall packet relays and delivered packet relays) are significantly increased, especially when the percentage of trusted nodes is less than 60%.



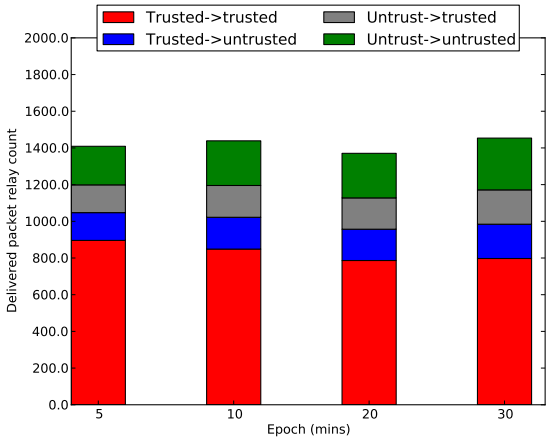
(a) Overall packet relay classification. Ephemeral ID valid for 1 epoch



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

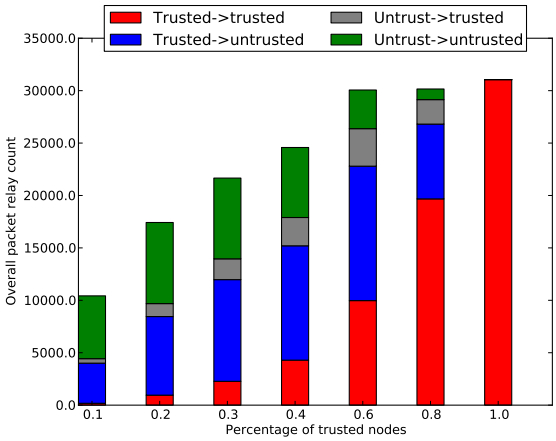


(c) Delivered packet relay classification. Ephemeral ID valid for 1 epoch

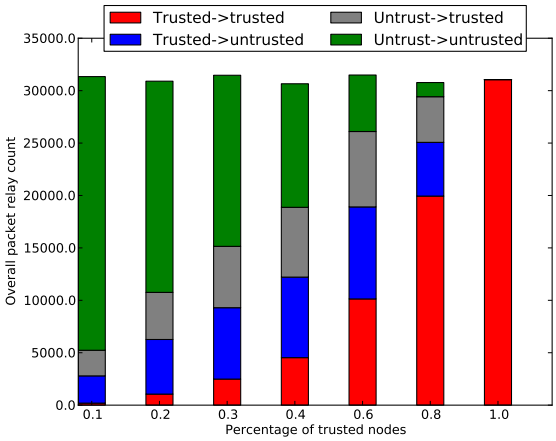


(d) Delivered packet relay classification. Ephemeral ID valid for 3 epochs

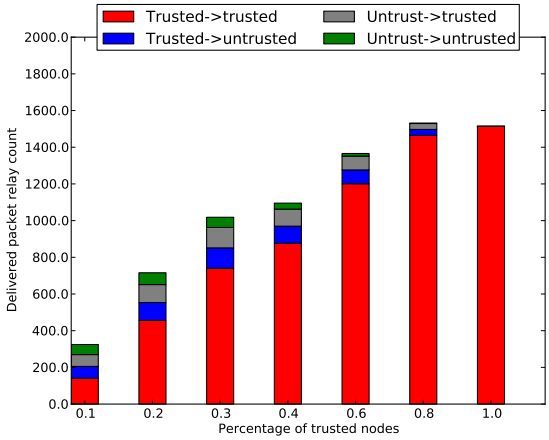
Figure 5: **Packet relay classification over varying epoch. Percentage of trusted nodes is** 30%**.** Relays between two trusted nodes account for 10% to 20% in overall packet relay classification, but relays between two trusted nodes account for more than 60% in delivered packet relay classification. In addition, relays between two untrusted nodes account for 25% to 50% in overall packet relay classification, but it accounts only for less than 15% in delivered packet relay classification.



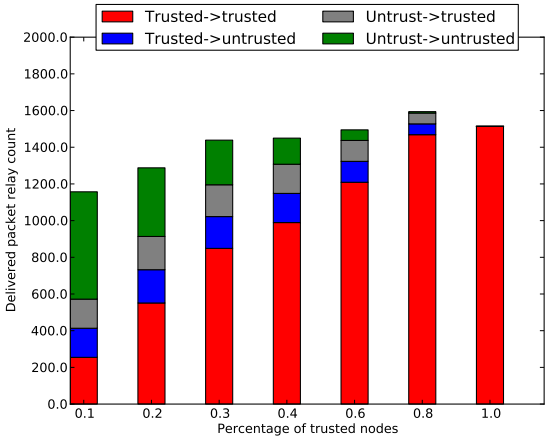
(a) Overall packet relay classification. Ephemeral ID valid for 1 epoch.



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

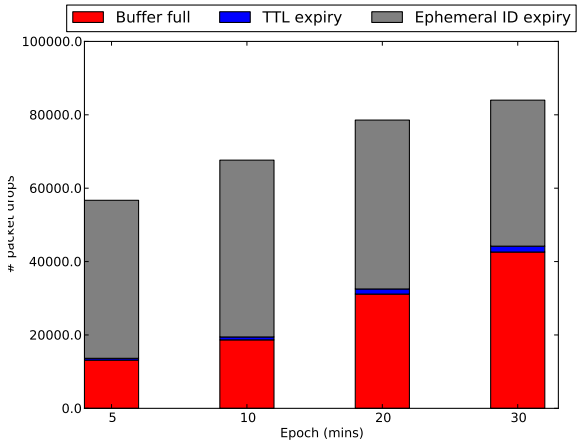


(c) Delivered packet relay classification. Ephemeral ID valid for 1 epoch.

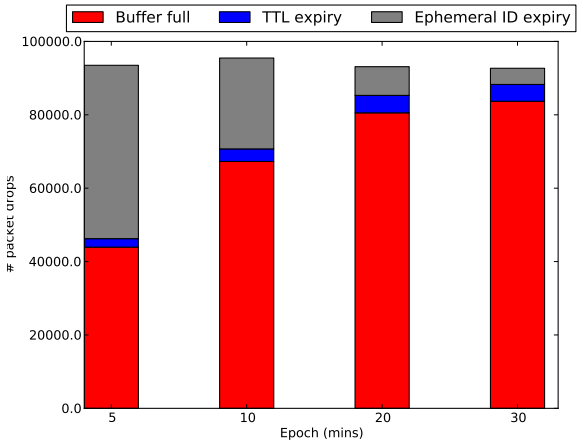


(d) Delivered packet relay classification. Ephemeral ID valid for 3 epochs.

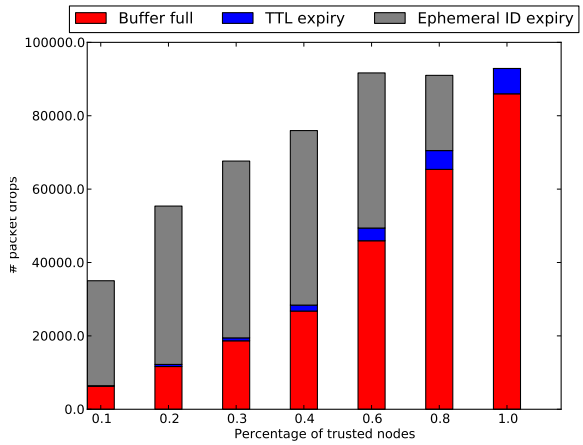
Figure 6: **Packet relay classification over varying percentage of trusted nodes. Epoch is 10 mins.** As in Figure 5, relays between two untrusted nodes account for relatively small part while relays between two trusted nodes account for the largest part (in most cases) in delivered packet relay classification.



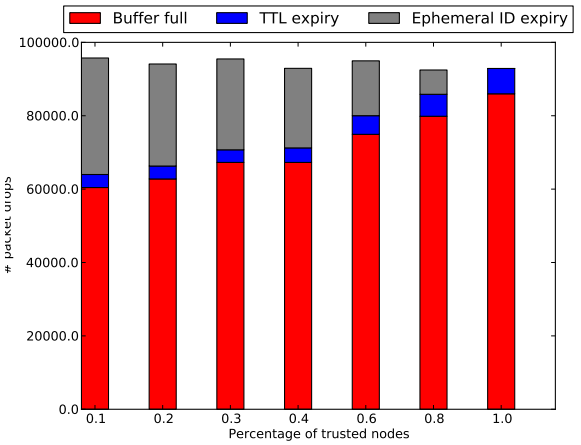
(a) Packet drops over varied epoch. Percentage of trusted nodes = 0.3. Ephemeral ID valid for 1 epoch.



(b) Packet drops over varied epoch. Percentage of trusted nodes = 0.3. Ephemeral ID valid for 3 epochs.

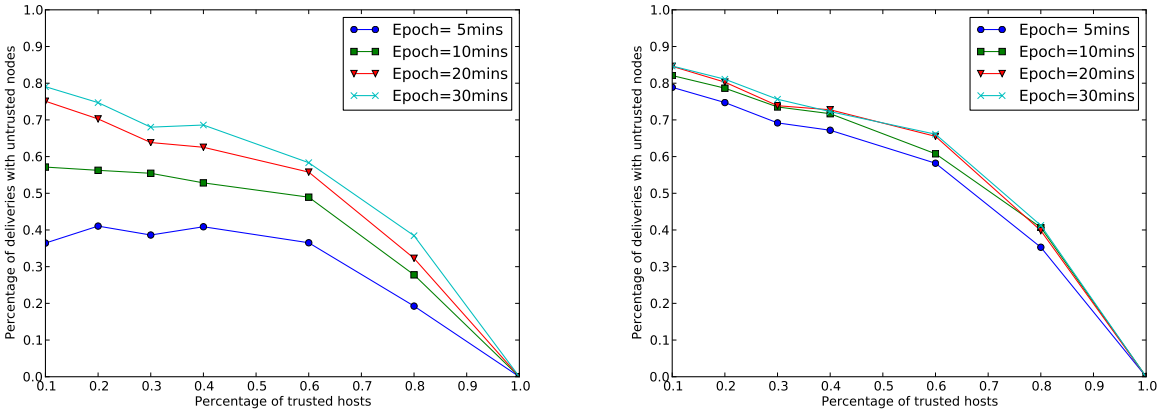


(c) Packet drops over varied percentage of trusted nodes. Epoch = 10 mins. Ephemeral ID valid for 1 epoch.



(d) Packet drops over varied percentage of trusted nodes. Epoch = 10 mins. Ephemeral ID valid for 3 epochs.

Figure 7: **Packet drop classification.** With ephemeral ID valid for 3 epochs (Figures 7b and 7d), the total number of packet drops is significantly increased compared to when ephemeral ID valid for 1 epoch is used (Figures 7a and 7c). However, most packet drops are due to buffer overflow, and packet drops due to ephemeral ID expiry is significantly decreased.



(a) Packet deliveries with untrusted nodes: Ephemeral ID valid for 1 epoch.

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

Figure 8: **Packet deliveries with untrusted nodes.** The number Packet deliveries including at least 1 untrusted node is significantly increased with the use of ephemeral ID valid for 3 epochs.