Controlling the Mobility of Multiple Data Transport Ferries in a Delay-Tolerant Network

Zhao Shu
2528498

Overview

- Background for the design of multi-ferry network
- Basic concept and terms
- Introduction to message ferrying network
- Four types of ferry route design algorithms
- Simulation results

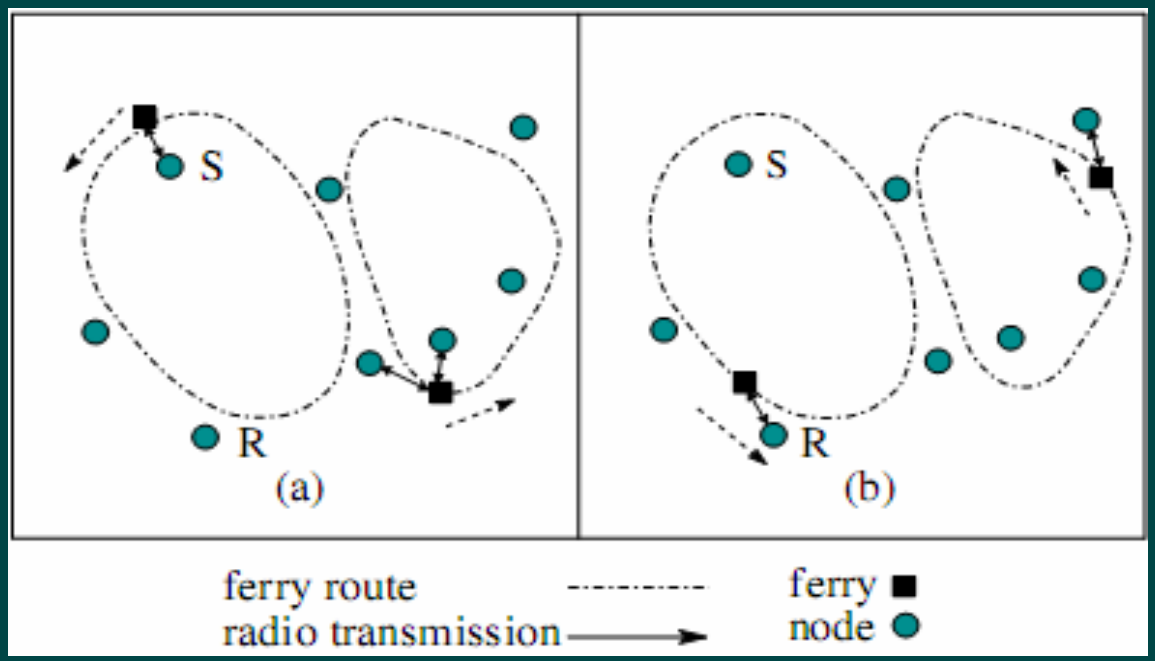
Background

Basic concepts and terms

- Proactive network vs. traditional network
- Message ferry
- Message ferrying network
- Ferry route
- Multiple ferries and stationary nodes

Message Ferrying Network

- Message Ferrying Scheme



Message Ferrying Network

- Network Model :

n stationary nodes;

m ferry nodes (m >= 1 and n >= m);

radio range r;

data rate of the radio w bps;

Message Ferrying Network

- Ferry Route Design

Weighted Delay D:

$$D = \frac{\sum_{1 \le i,j \le n} w_{ij} d_{ij}}{\sum_{1 \le i,j \le n} w_{ij}}$$

$w_{i,j}$ is weight while $d_{i,j}$ is average delay from node i to node j

Ferry Route Design Algorithm

- Three phases of the algorithm

(1) Assignment of nodes to ferries

(2) Calculation of ferry route

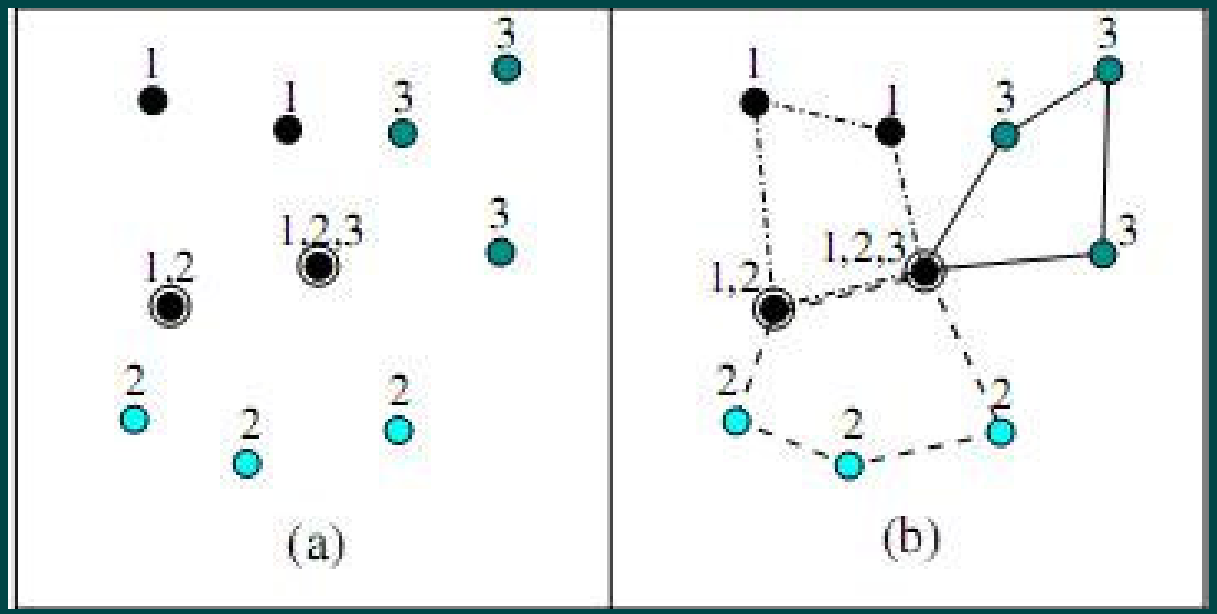
Goal —— Minimize the weighted delay

(3) Extension of ferry routes

Goal —— Meet bandwidth requirements

Ferry Route Design Algorithm

- Three phases of the algorithm



Ferry Route Design Algorithm

- Three types of Interaction between ferries

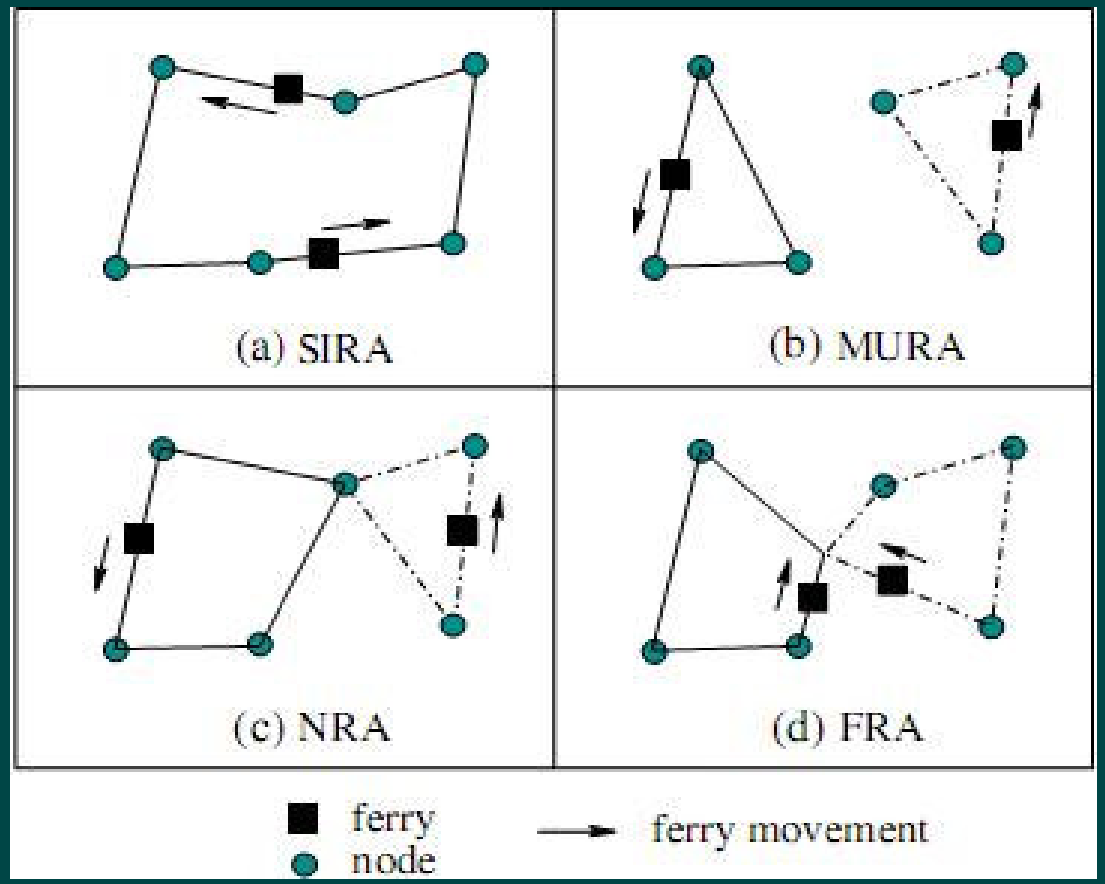
(1) No interaction;

(2) Ferry relaying;

(3) Node relaying;

Ferry Route Design Algorithm

- Four types of algorithms



Ferry Route Design Algorithm

- Single Route Algorithm (SIRA)

```
Compute an initial route using TSP heuristic algorithm;
do
    Apply 2-opt swaps;
    Apply 2H-opt swaps;
while (weighted delay is reduced);
Extend ferry route to meet bandwidth requirements;
```

Assume: L is the length of the ferry route, $l_{i,j}$ is the length from i to j, and f is the ferry speed,

Average delay for data from node i to node j is:

$D = l_{i,j} / f + L/(2mf)$

Ferry Route Design Algorithm

- Single Route Algorithm (SIRA)

Travelling Salesman Algorithm:

Start from node 1, each time go to the nearest node not visited yet. Once all the nodes have been visited, return to the starting node 1.

Ferry Route Design Algorithm

- Single Route Algorithm (SIRA)

Bandwidth requirement —— detour in the vicinity of nodes as short as necessary.

$$\frac{(x_i + 2r)W}{L + \sum_{j=1}^{n} x_j} \geq \frac{s_i}{m}$$

x_i is the length of detour in the vicinity of node i;

r is the radio range;

s_i is the total data rate for node i;

Ferry Route Design Algorithm

- Single Route Algorithm (SIRA)

Bandwidth requirement —— detour in the vicinity of nodes as short as necessary.

$$\text{minimize} \quad \sum_{i=1}^{n} x_i,$$

$$\text{subject to} \quad mW x_i - s_i \sum_{j=1}^{n} x_j \geq s_i L - 2mrW,$$

$$x_i \geq 0 \text{ and } 1 \leq i \leq n.$$

Ferry Route Design Algorithm

- Multi- Route Algorithm (MURA)

EWD(op): EWD of node assignment after operation op

Set the number of ferries to n;
Assign each node to a ferry;
while number of ferries $> m$ **or** EWD is reduced **do**
    Identify the best *overlap* or *merge* operation op_s;
    Identify the best $merge^-$ or *reduce* operation op_l;
    if EWD(op_s) $<$ EWD(op_l) **and**
      EWD(op_s) $<$ current EWD **then**
        Perform op_s;
    else
        Perform op_l;

Refine node assignment to maintain feasibility;
Compute each ferry route;

Ferry Route Design Algorithm

$$E^* = \begin{cases} \omega L(1+\alpha-\mu) & \text{if } \alpha \geq \mu; \\ 0 & \text{if } \alpha < \mu; \end{cases}$$

$$E' = \begin{cases} 0 & \text{if } \alpha \geq \mu; \\ \omega L(1+\frac{1}{k})(1+\frac{\alpha}{\mu-\alpha}) & \text{if } \alpha < \mu. \end{cases}$$

Estimated Weighted Delay (EWD) is a two-component tuple (E*, E') where

α is total data rate and μ is maximum data rate which equals 0.5kWbps.

w is weight of traffic, and L is length of a TSP route.

k is the number of ferries in the route.

Ferry Route Design Algorithm

E* is the more significant component when comparing two EWDs, so (E1*, E1') > (E2", E2'), if E1* > E2* or E1* = E2* and E1' > E2'.

factor (1 + 1/k) accounts for the impact of traffic load;

factor $(1 + \alpha / (\mu - \alpha))$ is set to meet the bandwidth requirement.

Ferry Route Design Algorithm

- Multi-Route Algorithm (MURA)

Assignment of nodes to ferries:

i and j represent two routes

(1) Overlap (i, j)

(2) Merge (i, j)

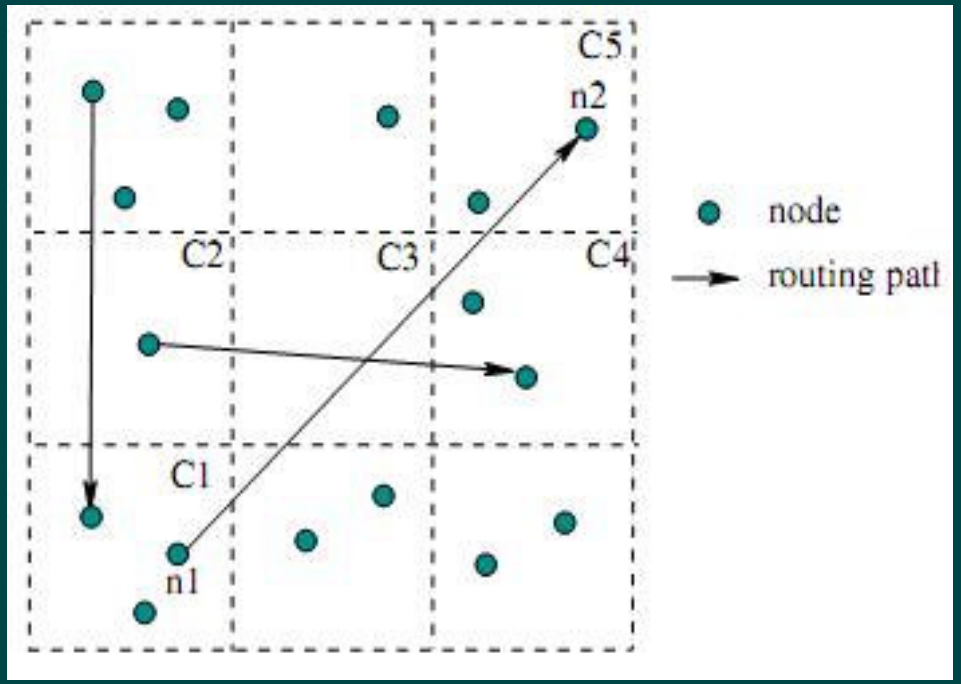
(3) Merge^{-} (i, j)

(4) Reduce (i)

Ferry Route Design Algorithm

- Node Relaying Algorithm (NRA)

NRA uses geographic routing, where data is forwarded along cells that connects the source and destination.



Ferry Route Design Algorithm

- Node Relaying Algorithm (NRA)

Two types of empty cells

(1) with traffic forwarded through the cell;

(2) without traffic forwarded through the cell.

How to pick up relaying node?

Ferry Route Design Algorithm

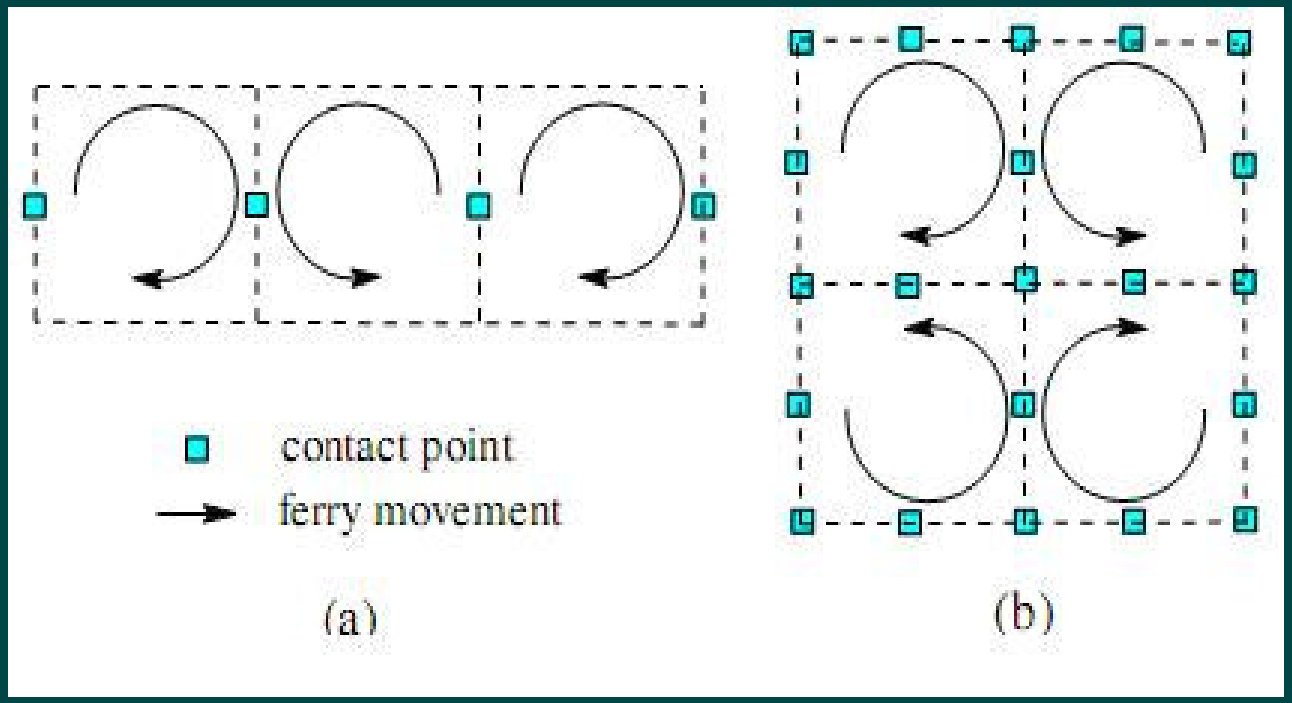
- Ferry Relaying Algorithm (FRA)

(a) Synchronization between ferry routes:

- All routes have the same length;
- Contact points (where ferries meet) partition each ferry route into segments of the same length;
- Ferries in neighboring cells move in reverse direction.

Ferry Route Design Algorithm

- Ferry Relaying Algorithm (FRA)



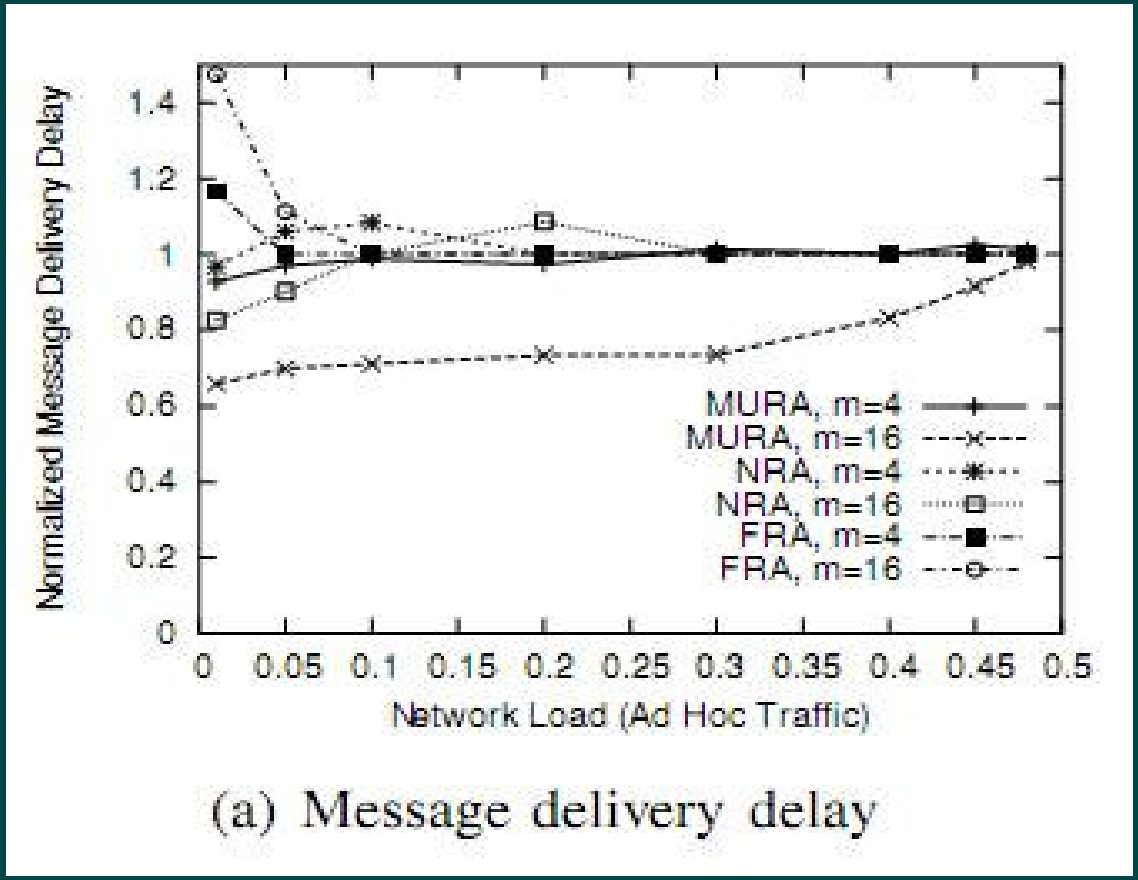
Ferry Route Design Algorithm

- Ferry Relaying Algorithm (FRA)

(b) Calculation of ferry routes:

Simulation Results

- Average Weighted Delay:



(a) Message delivery delay

Simulation Results

- Average Weighted Delay:

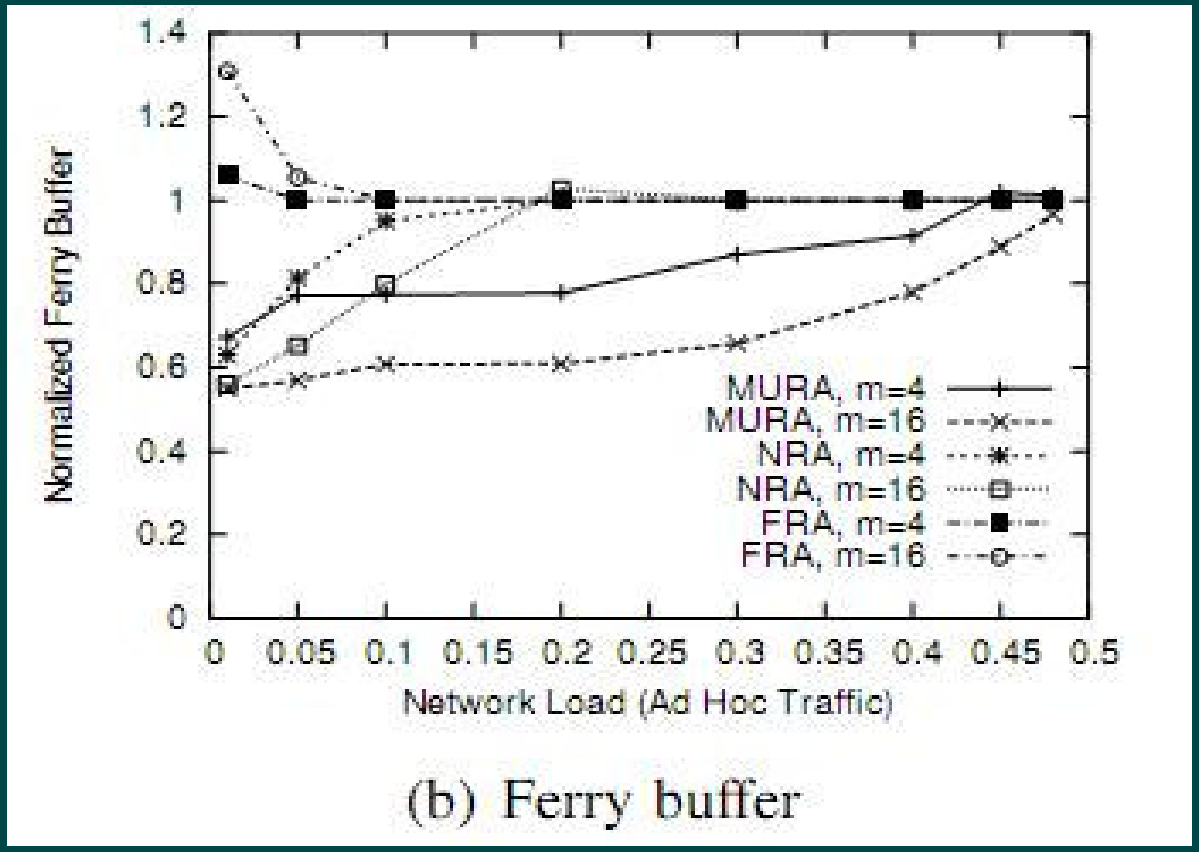
When traffic load is high or number of ferries is small, weighted delay achieved is the same;

MURA achieves the least delay when the number of ferries is large whereas FRA performs worst,

why is the result?

Simulation Results

- Ferry Buffer Requirement



(b) Ferry buffer

Simulation Results

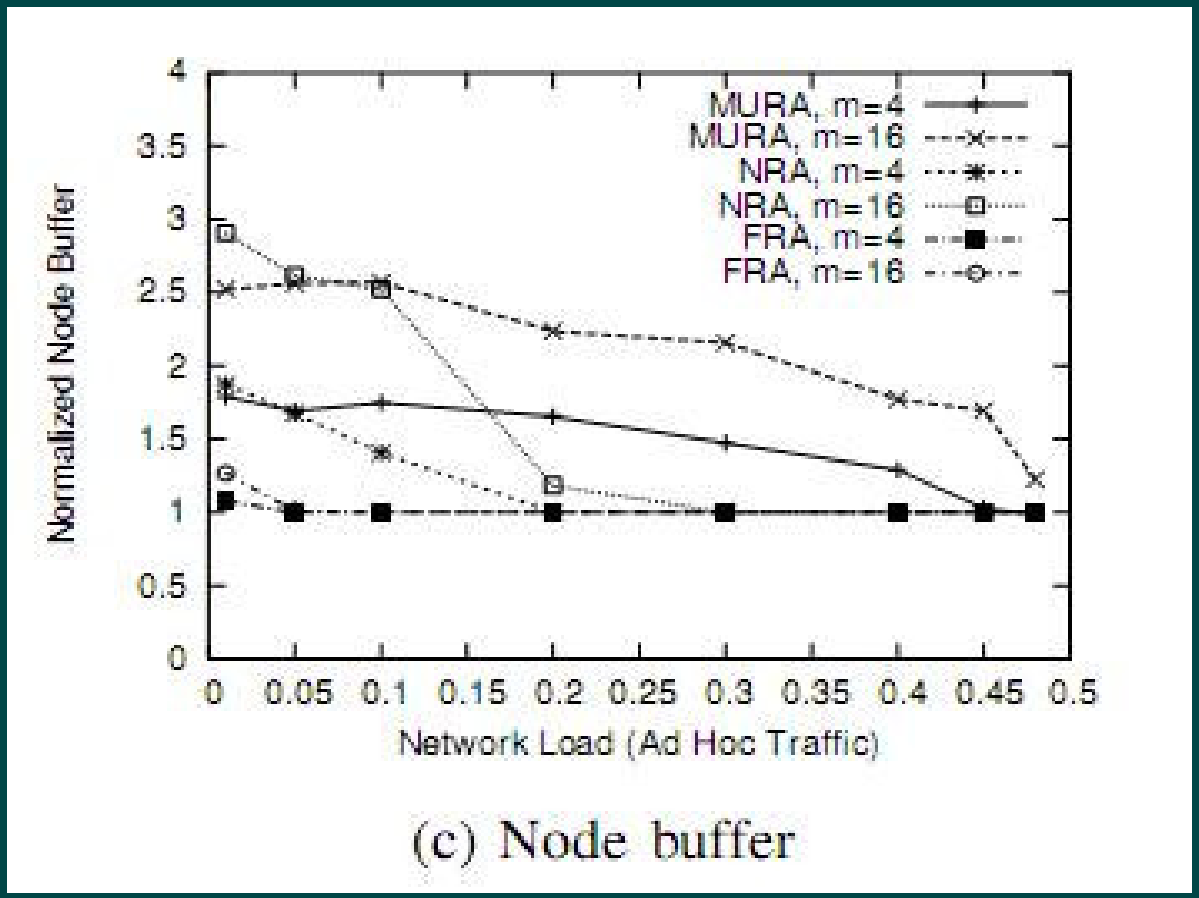
- Ferry Buffer Requirement

Both NRA and MURA require less ferry buffer than SIRA, why?

FRA needs more buffer because of route synchronization.

Simulation Results

- Node Buffer Requirement



(c) Node buffer

Simulation Results

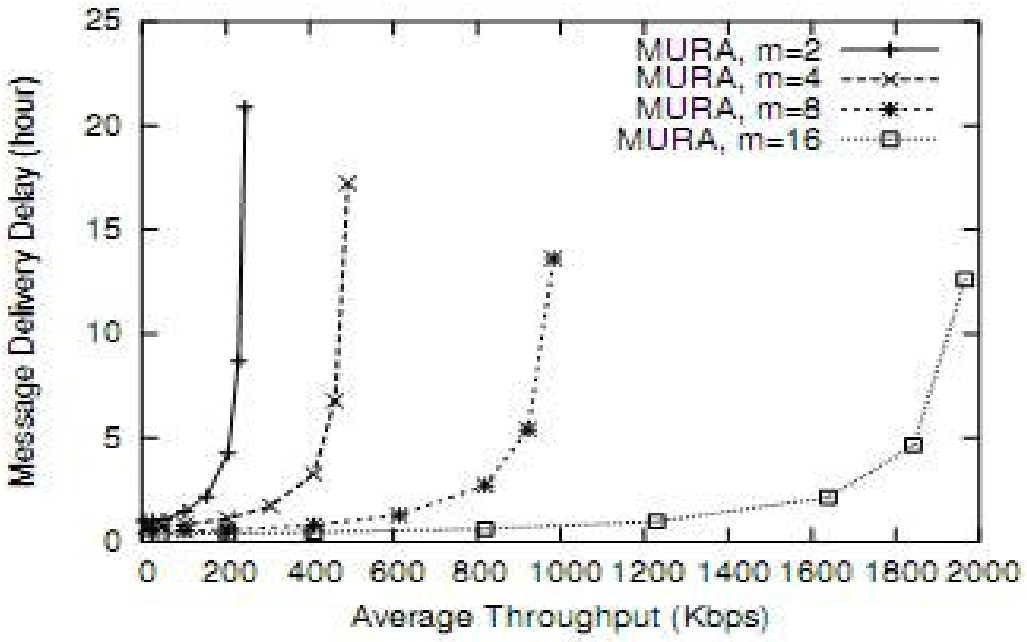
- Node Buffer Requirement

SIRA uses the smallest number of node buffer, as node buffer is determined by average time between contacts of ferries;

Simulation Results

- Impact of Traffic Load

(1) On weighted delay:



(a) Message delivery delay

Simulation Results

- Impact of Traffic Load

(1) On weighted delay:

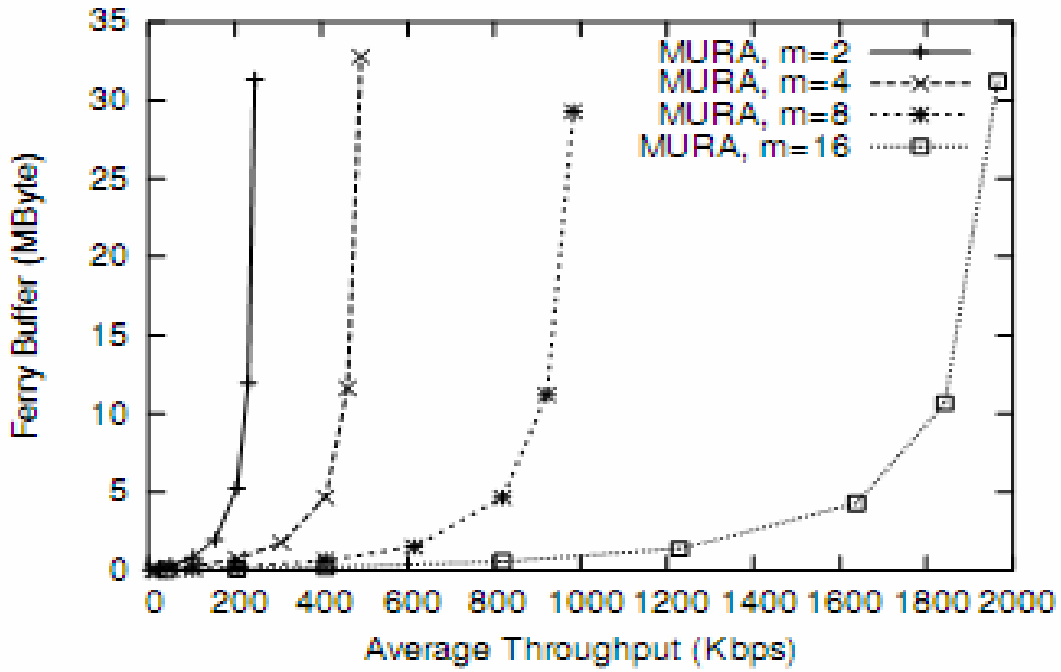
For a given traffic load, the delay decreases when the number of ferries increases;

When the traffic load is high, the increase in the number of ferries can dramatically reduce the delay.

Simulation Results

- Impact of Traffic Load

(2) On ferry buffer:

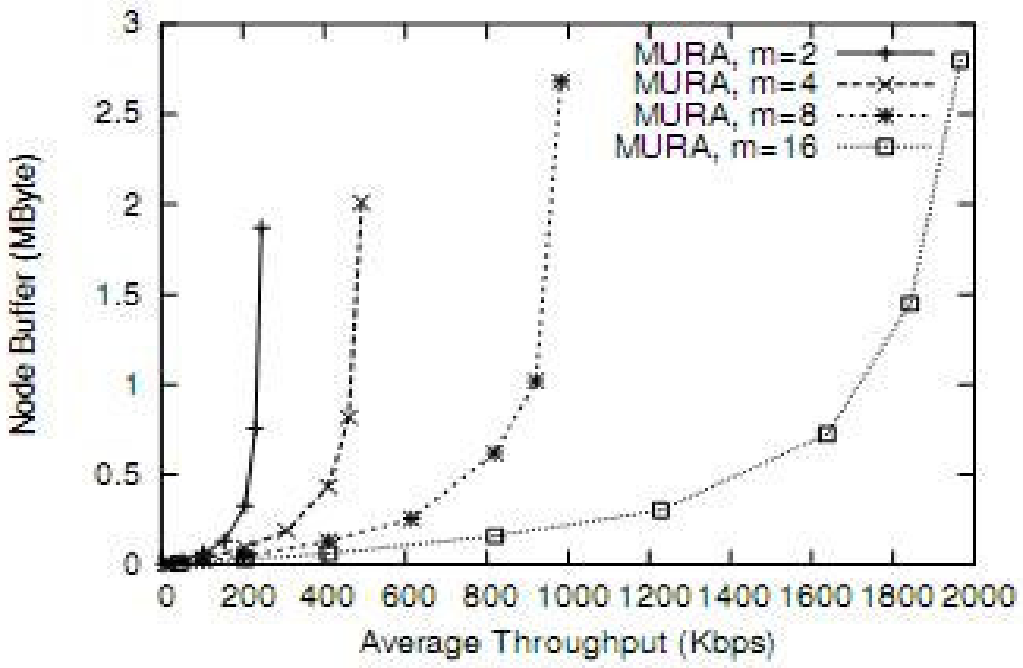


(b) Ferry buffer

Simulation Results

- Impact of Traffic Load

(3) On node buffer:

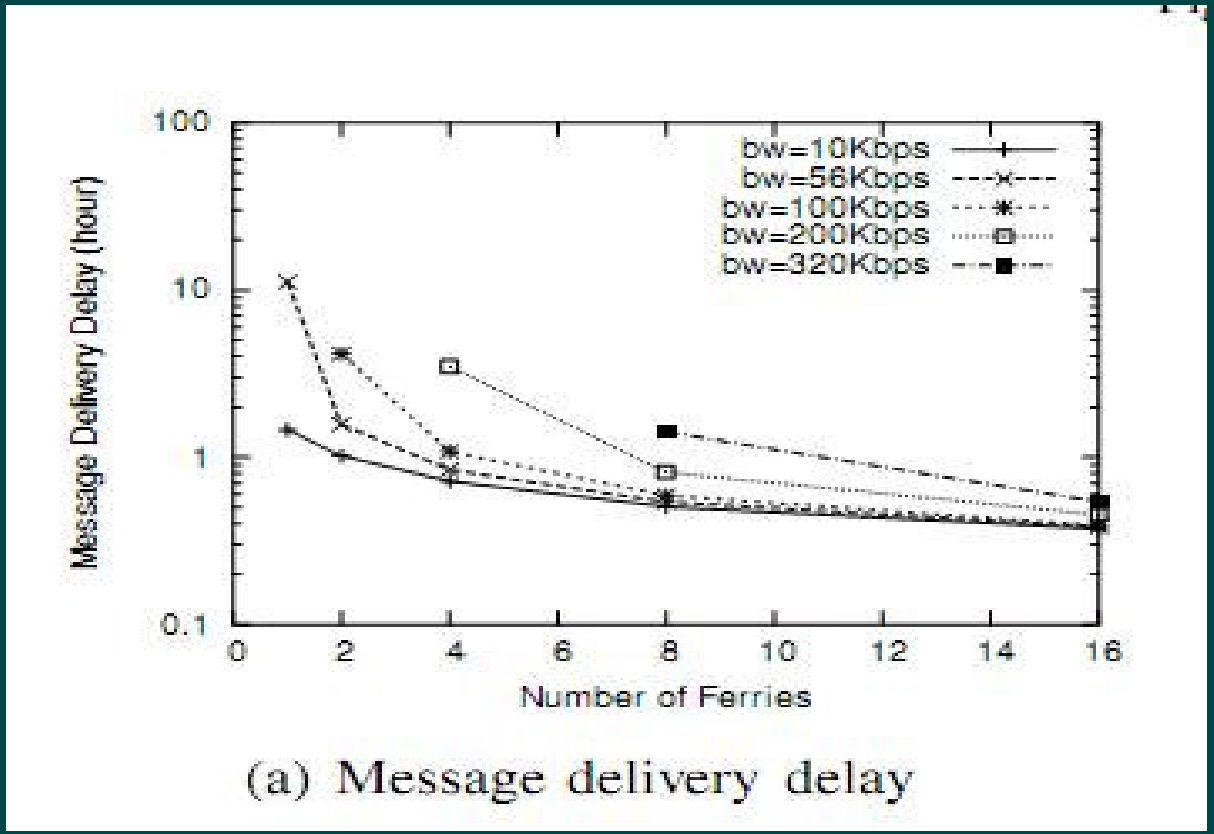


(c) Node buffer

Simulation Results

- Impact of number of ferries

(1) On weighted delay:



(a) Message delivery delay

Simulation Results

- Impact of number of ferries

(1) On weighted delay:

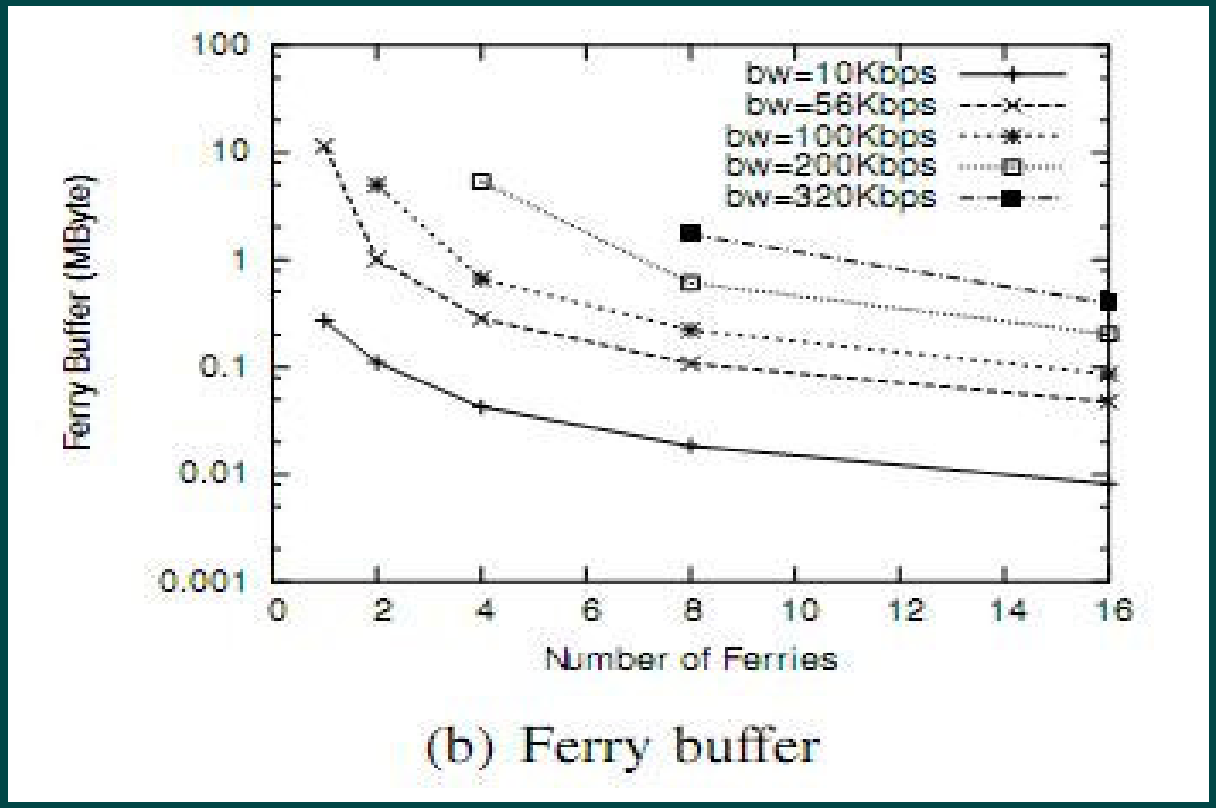
For a given traffic load, as the number of ferries increases, the delay decreases;

Because each ferry needs to carry less data, or each ferry needs to visit smaller number of nodes.

Simulation Results

- Impact of number of ferries

(2) On ferry buffer:

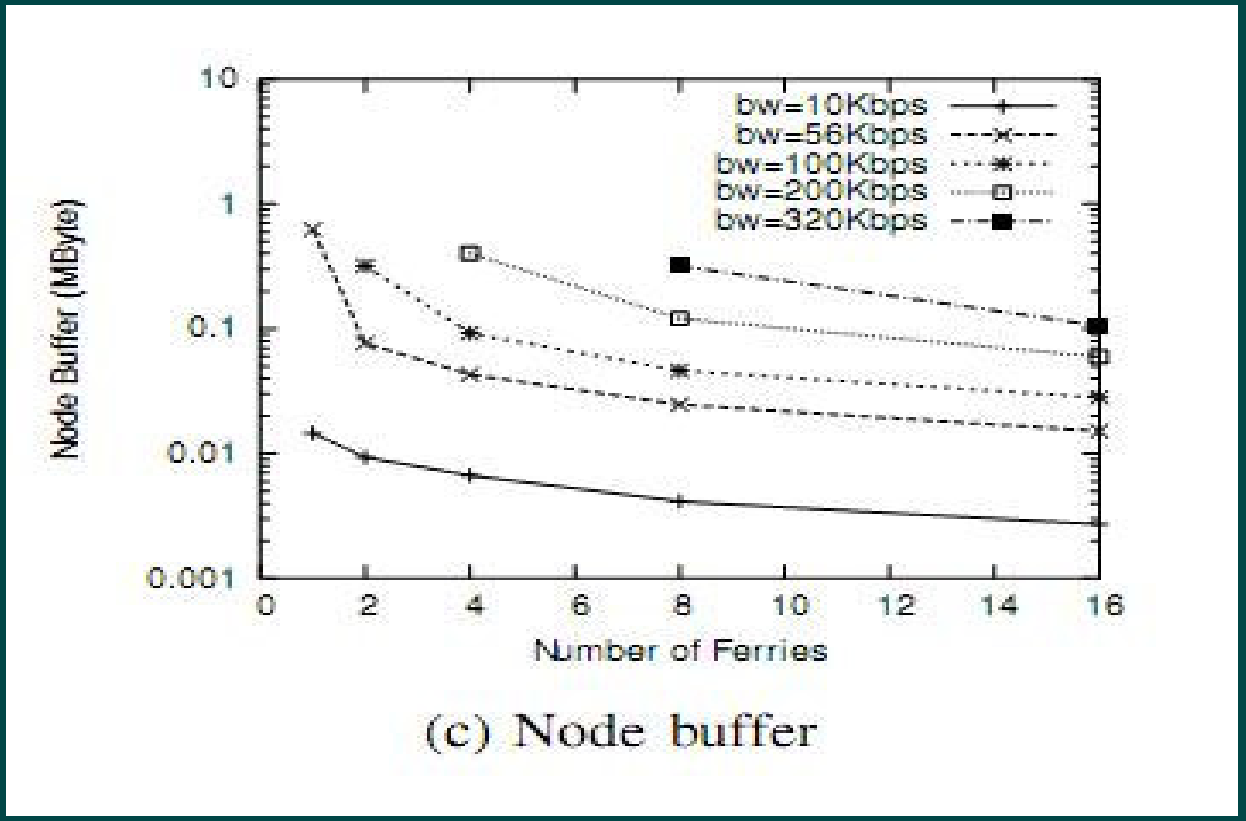


(b) Ferry buffer

Simulation Results

- Impact of number of ferries

(3) On node buffer:



(c) Node buffer

THANK YOU☺

Nice Evening!