Analysis of Cluster Ring Controller/Area Networks for Enhanced Transmission and Fault Tolerance in Vehicle Networks

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outline

- Introduction
- Cluster CAN Topology
- Injection Rate Model Construction
- Link Fault Model Construction
- Simulation Result
- Conclusion

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Introduction

- The vehicle with CAN network is a popular solution with low cost.
- The bandwidth is not sufficient for many components in a vehicle system.
- Two ClusterCAN topologies were proposed to resolve the bandwidth issue.
  -ring topology is required to achieve component clustering.
  -single ring two phase clusterCAN topology.
  -dual ring two phase clusterCAN topology.

Introduction

- With bandwidth increased, a proper estimate of injection rate of each component can prevent the system overloading.
- We provide a theoretical model analysis for different cluster CAN topologies.
- We also provide an injection rate model under fault link situation.
- We set up a simulation environment to verify the proposed model.

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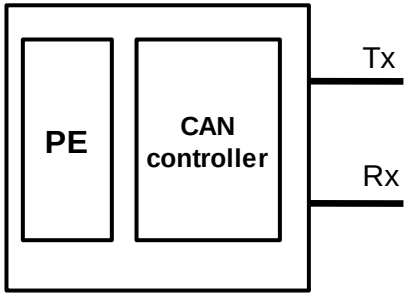
Cluster CAN Method

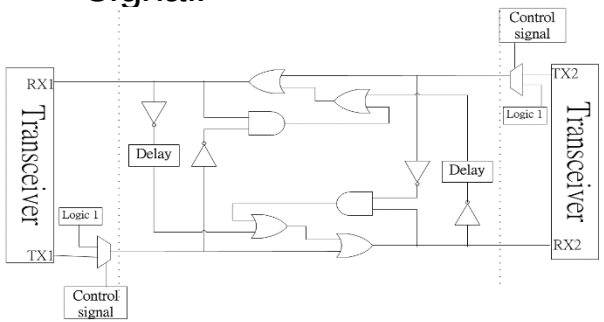
N_i

The node unit of the CAN system. It has the CPU and the CAN controller in it.

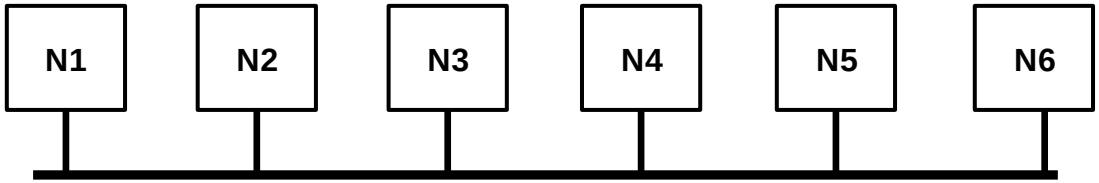


S

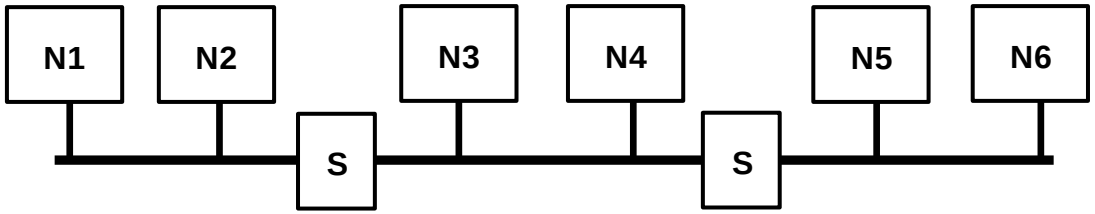
The switch of the CAN system. It is a repeater with the control signal.



Original CAN Bus



Cluster CAN Bus



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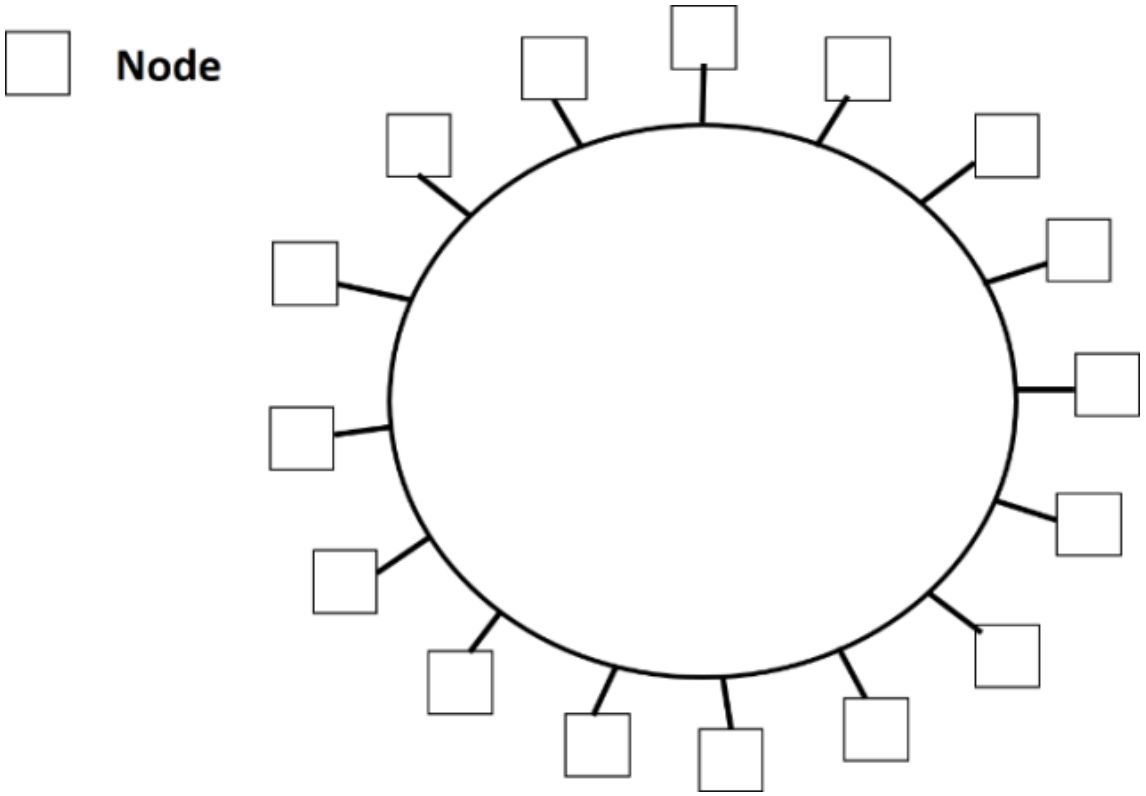
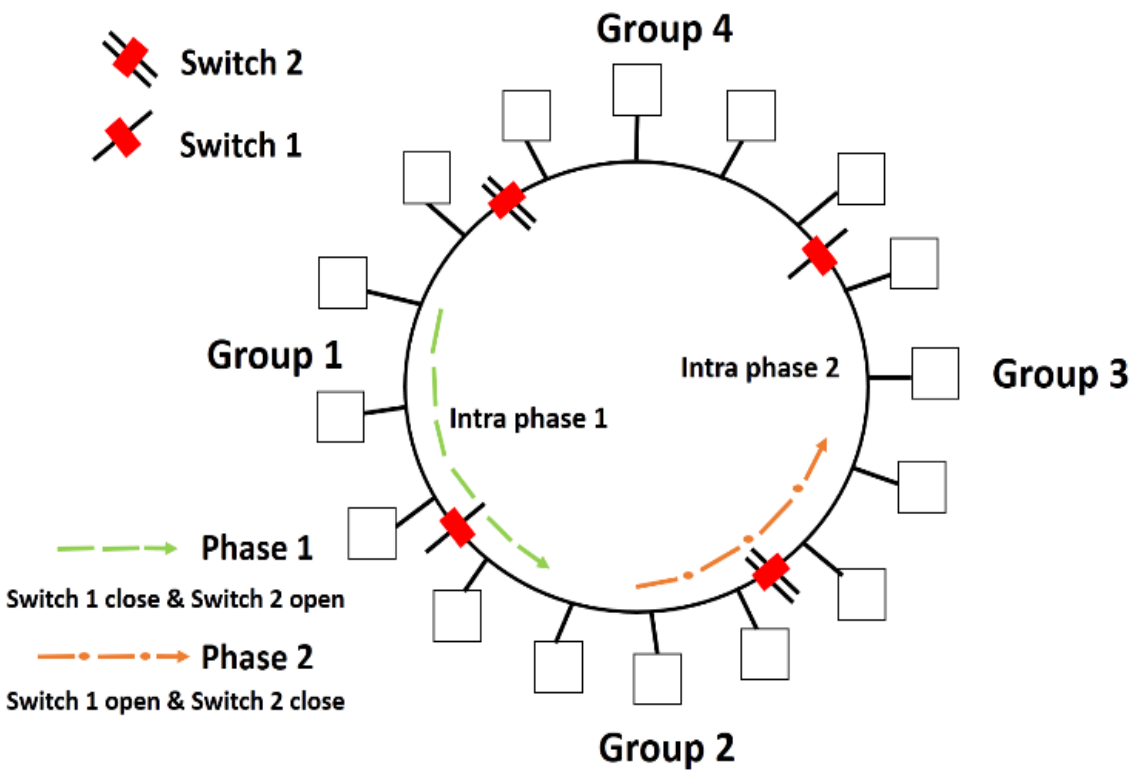
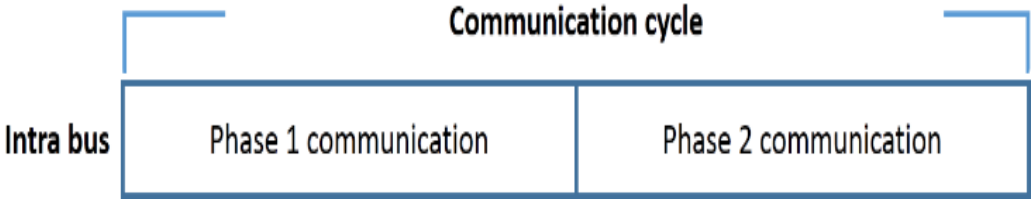
Single Ring Topology

- N nodes with fixed and unique priorities.

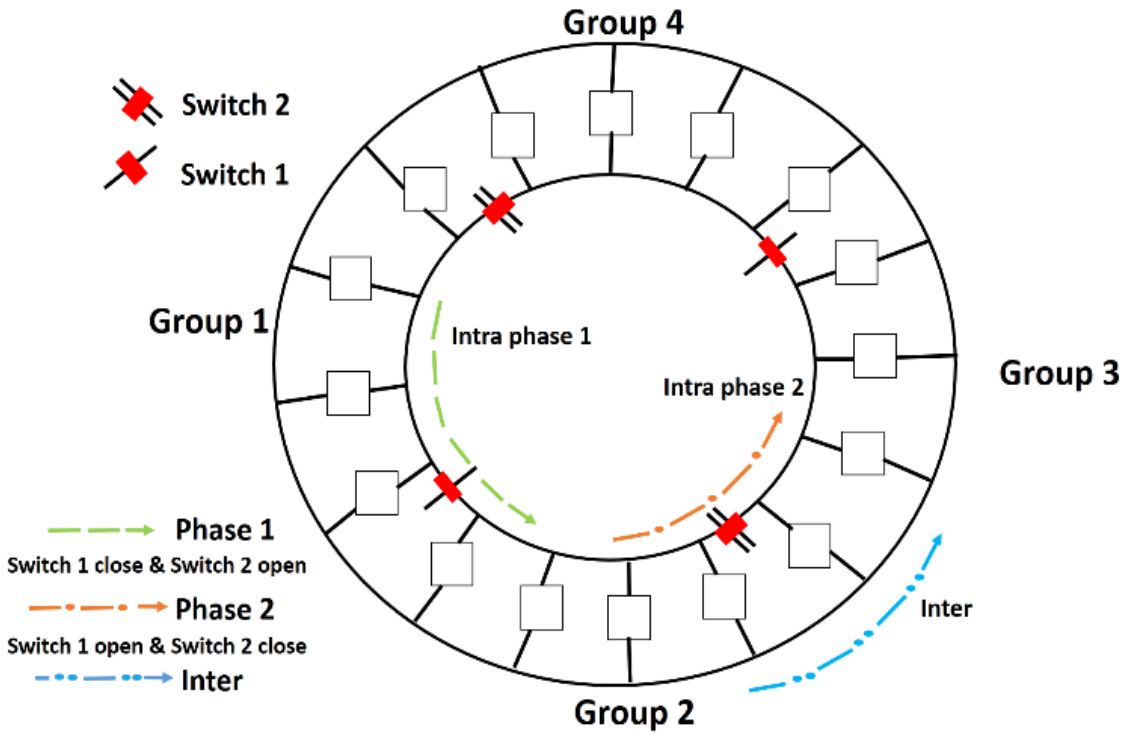


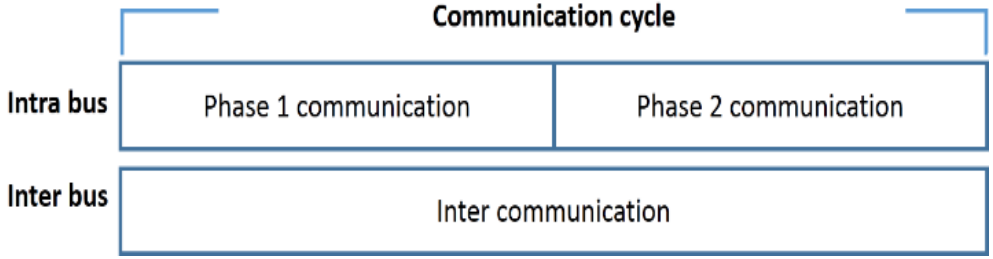
Single Ring 2 Phase Topology





Dual Ring 2 Phase Topology





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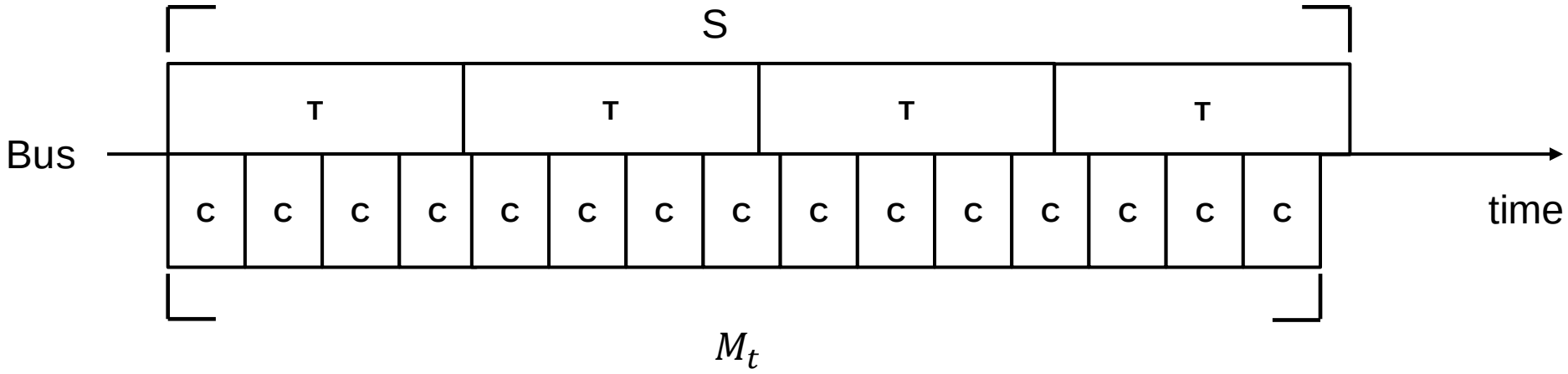
Injection Rate Model Construction



$$M_t = S \times T \div C$$

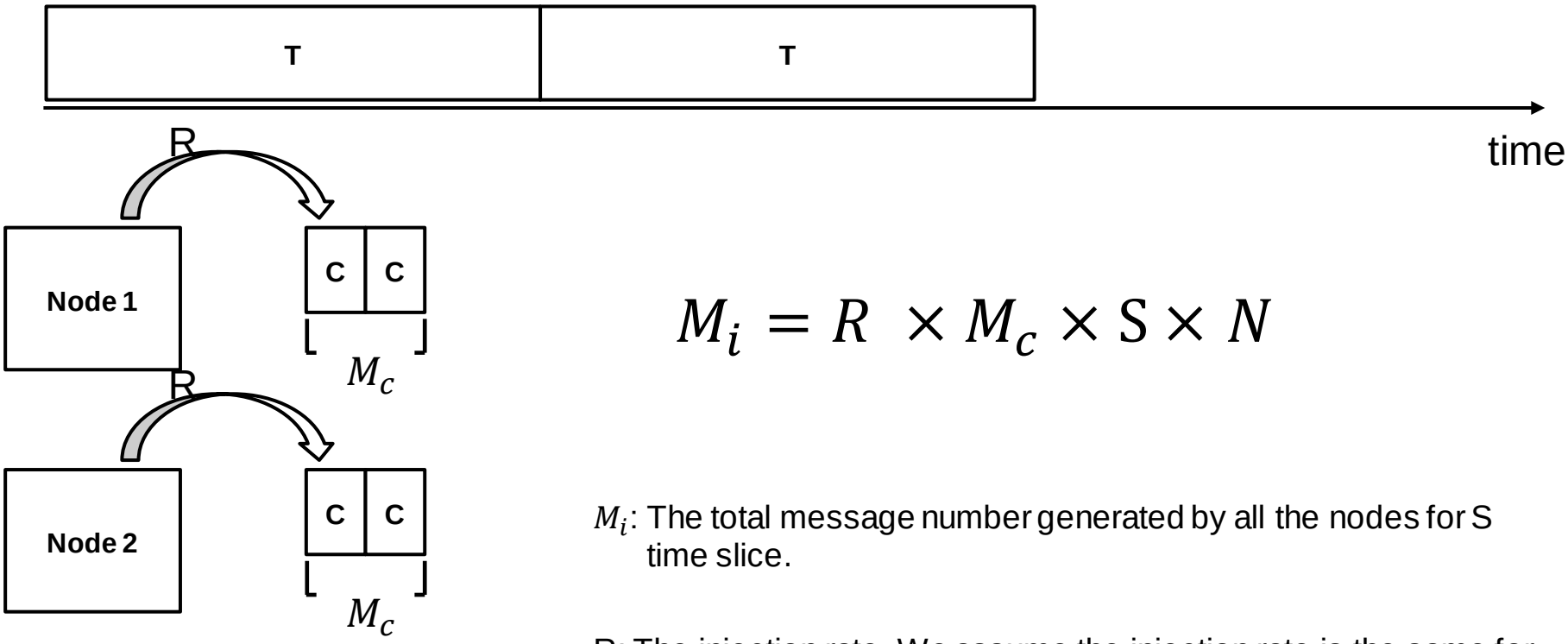
S: Total time slices number of a simulation.

T: Period of time slice and the unit is millisecond (ms).

C: Maximum transmission time of a message and the unit is millisecond (ms).

M_t: The maximum number of messages that a bus can transmit.

Injection Rate Model Construction



$$M_i = R \times M_c \times S \times N$$

M_i: The total message number generated by all the nodes for S time slice.

R: The injection rate. We assume the injection rate is the same for all the nodes.

M_c: The message number created by nodes per time slice.

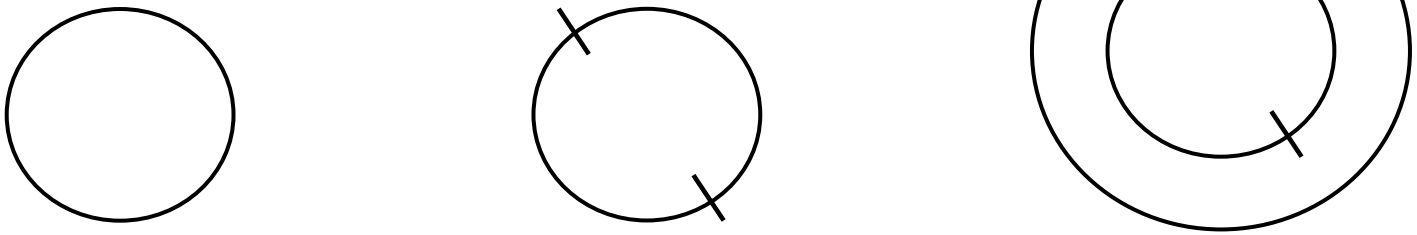
N: Total node numbers.

Injection Rate Model Construction

Let the maximum number of messages that a bus can transmit (M_t) equals to the total message number generated by all the nodes (M_i).

Let $M_t = M_i$, we can get the maximum injection rate R_{max}:

$$R_{max} = T \div C \div N$$



model as: 1 bus 2 bus 3 bus

$$R_{max} = = \begin{cases} T \div C \div N & \text{single ring topology} \\ 2 \times T \div C \div N & \text{single ring 2 phase topology} \\ 3 \times T \div C \div N & \text{dual ring 2 phase topology} \end{cases}$$

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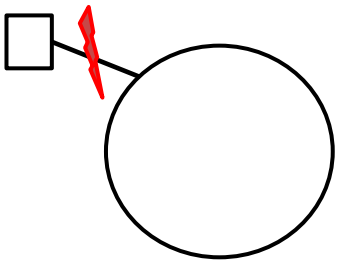
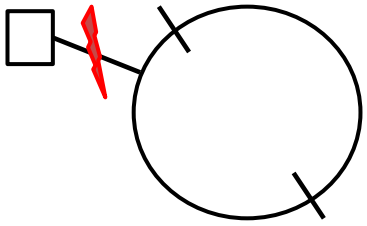
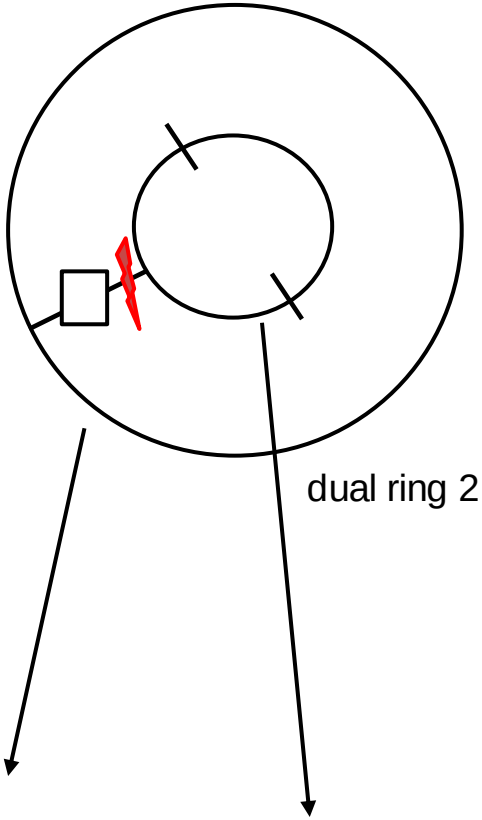
Link Fault Model Construction



Single ring



Single ring 2 phase



dual ring 2 phase

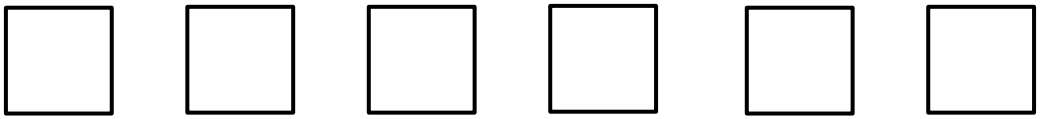
Assume the link fault occur only in intra bus.

Once link fault occur, R=0 for single ring topology and single ring two phase topology.

Separate the contribution of inter and intra bus for dual ring two phase topology:

$$R_{max} = \frac{T}{C \times N} + 2 \times \frac{T}{C \times N}$$

Link Fault Model Construction



Priority:	1	2	3	4	5	6
Weight(W_i)	6	5	4	3	2	1

W: The total weight of the topology.= $\sum W_i$

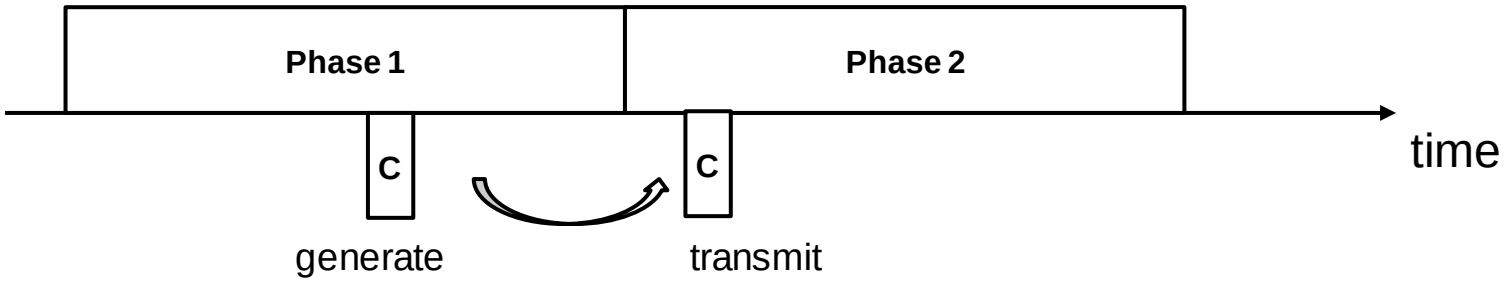
W_f: The sum of the link fault weight of the topology.

Ex: W=21,
And node 2, 3, link fault,
$W_f = 9$

R_f: The sum of the link fault weight of the dual ring two phase topology.

$$R_{f.max} = \frac{T}{C \times N} + 2 \times \frac{T}{C \times N} \times \frac{W - W_f}{W}$$

Link Fault Model Construction

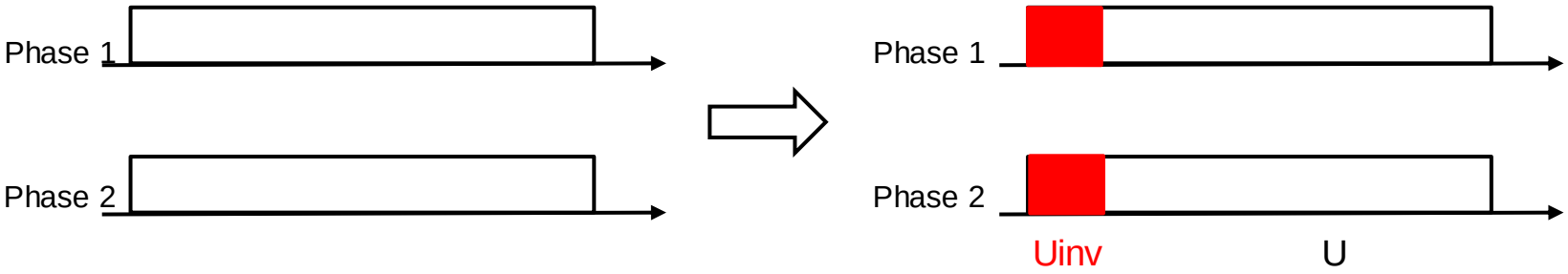


No cross-group message

Full parallel: U=100%

cross-group message

With overhead: U<100%

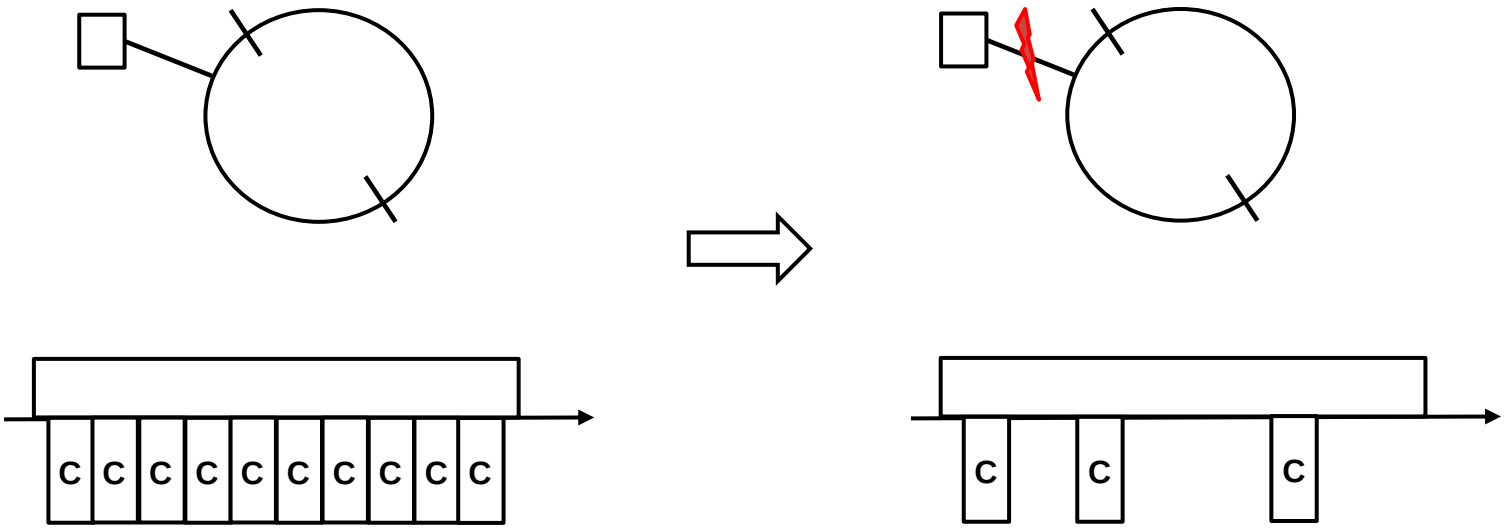


$$U = 1 - U_{inv}$$

U: the cluster CAN bus utilization.

U_{inv}: The cluster CAN bus utilization with cross group message transmission

Link Fault Model Construction



$$R_{f.max} = \frac{T}{C \times N} + 2 \times \frac{T}{C \times N} \times \frac{W - W_f}{W} \times \left(U + U_{inv} \times \frac{L_f}{N} \right)$$

L_f: The link fault number of a topology. The link fault is the fault for transmission from the node to the ring bus.

Link Fault Model Construction

- The overall maximum injection rate in three topologies:

$$R_{f.max} = \begin{cases} 0, & if \ \ L_f > 0, \quad single\ ring\ topology \\ 0, & if \ \ L_f > 0, \quad single\ ring\ 2\ phase\ topology \\ \dfrac{T}{C \times N} + \dfrac{2 \times T}{C \times N} \times \dfrac{W - W_f}{W} \times \left(U + U_{inv} \times \dfrac{L_f}{N} \right), & dual\ ring\ 2\ phase\ topology \end{cases}$$

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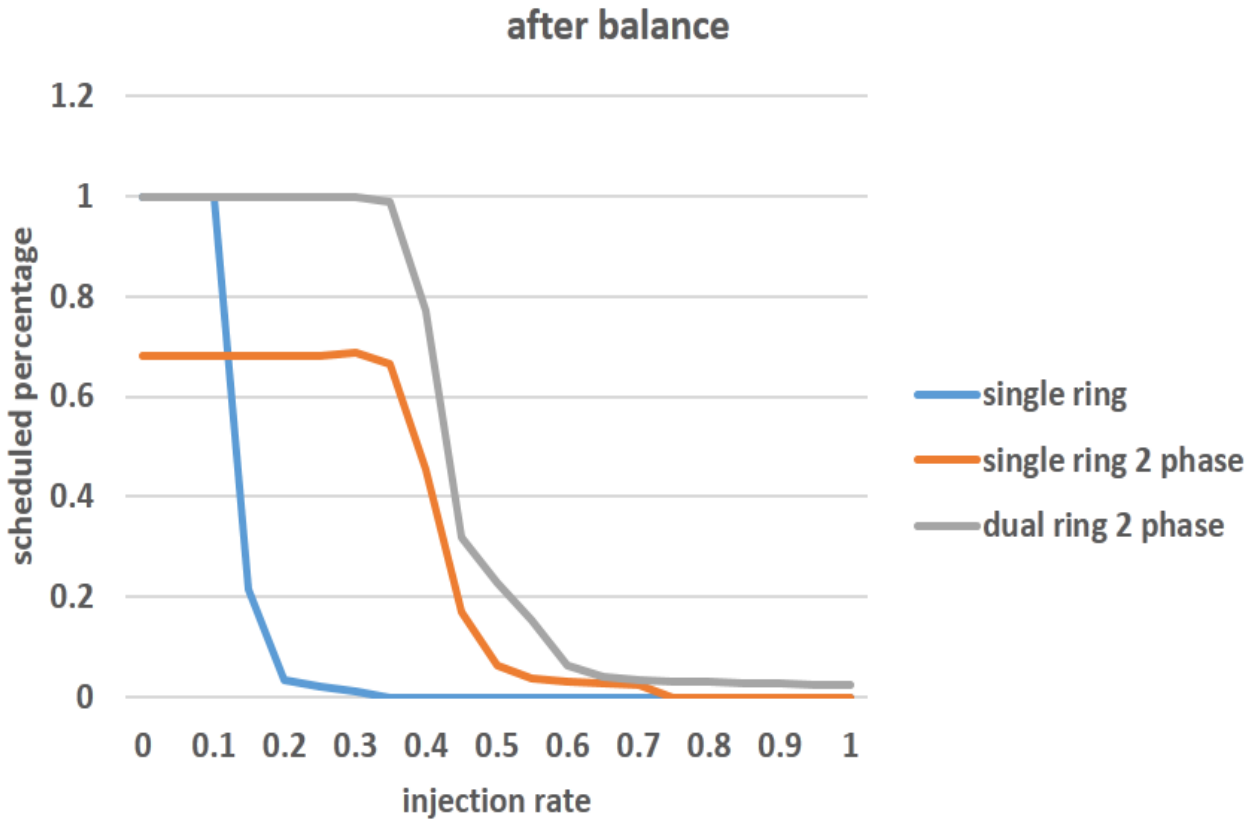
Simulation Setup

- Nodes(N) = 16
- Time period(T) = 0.5
- Message transmission time(C) = 0.25
- Time slice(S) = 1000
- Total simulation time slice = 2000
- Random traffic generation

Simulation Result(1)

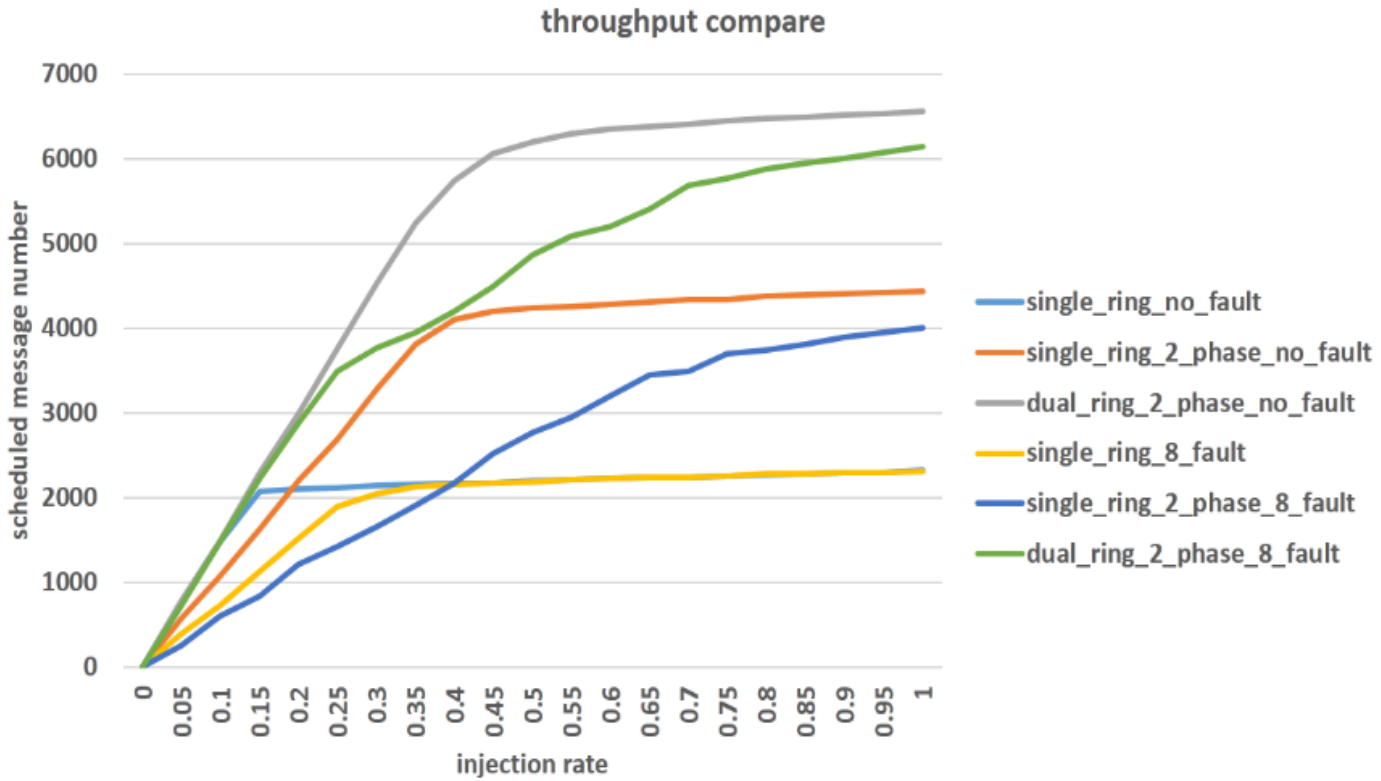
Scheduled message percentage define:

worst nodes ($^{scheduled\ message\ number}/_{total\ message\ number}$)



Simulation Result(2)

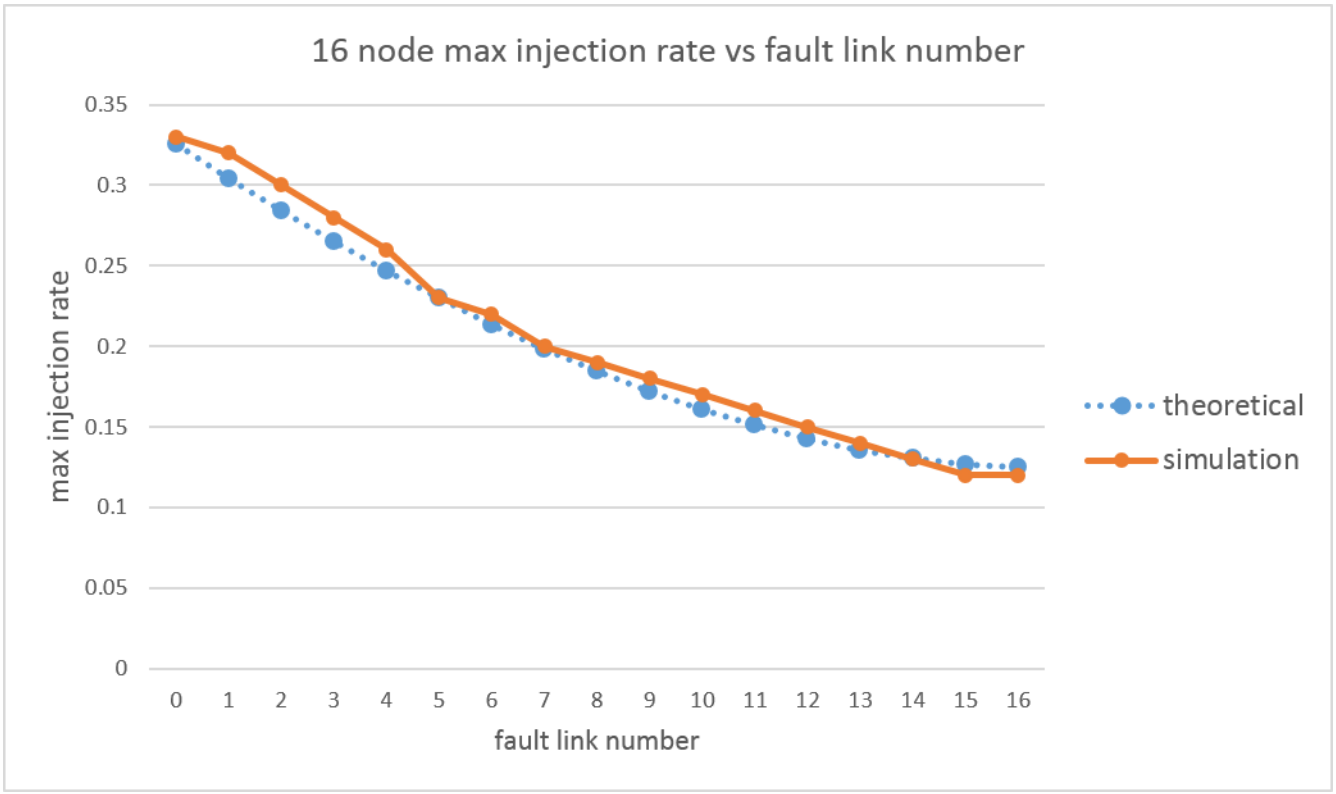
- throughput vs injection rate



Simulation Result(3)

- **Compare theoretical and simulation result.**

$R_{f.max}$



L_f

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Conclusion

- We provide a theoretical model to analyze the injection rate and scheduled messages in different topologies.
- Under this model, we can estimate injection rate of every node correctly when link fault occurs.
- It helps to figure out the data scale should be injected into a CAN system in different topologies.

Thanks for your attention.

Reference

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