Multi-Hop Broadcast from Theory to Reality: Practical Design for Ad Hoc Networks

Alaeddine EL-FAWAL

Joint work with

Jean-Yves Le Boudec, Kavé Salamatian

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OUTLINE

- Introduction
- SLEF Middleware: Self Limiting Epidemic Forwarding
- Performance Validation
- SLEF vs. K-Hop broadcast
- Conclusions

Why Multi-Hop Broadcast?

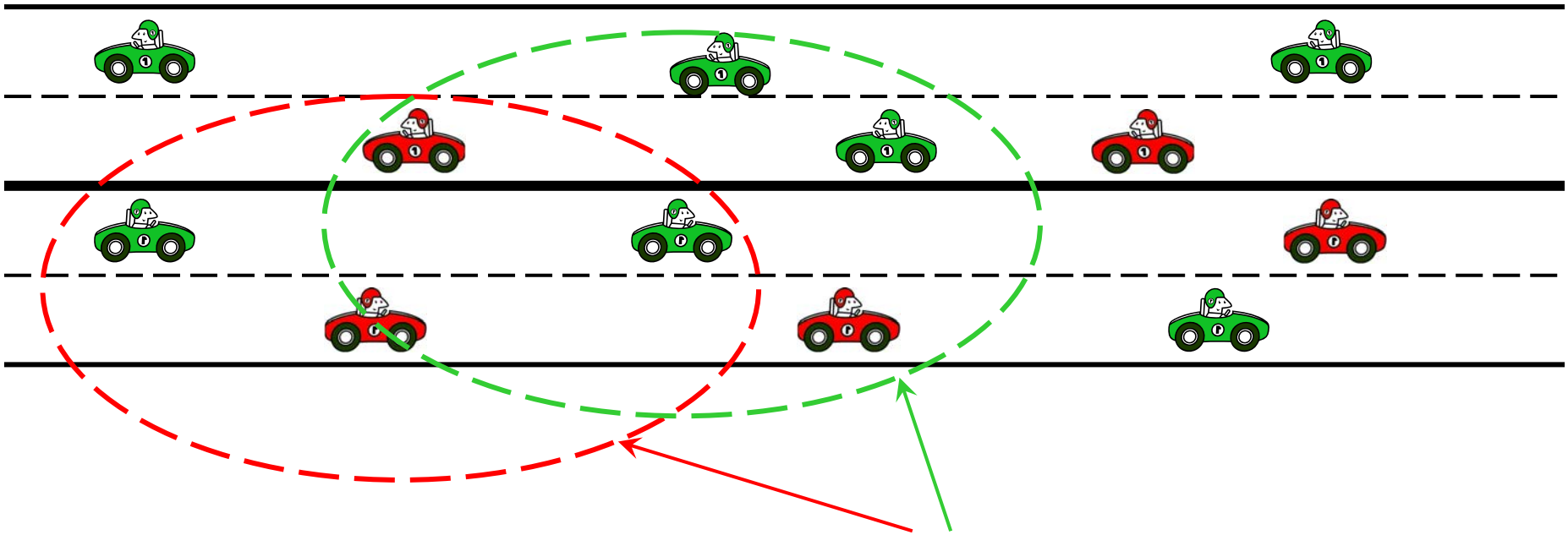
⇨ Information dissemination:

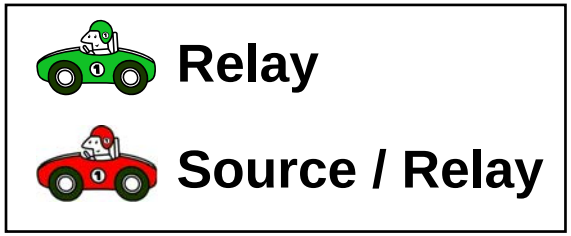
- ✓ Opportunistic communications
- ✓ High mobility where classical methods based on distribution trees fail.
- ✓ Support routing, resource discovery, bootstrapping phases for application layer.

⇨ Broadcast application:

- ✓ Disseminating traffic info in vehicular networks.
- ✓ Chat on the highway / in a crowd / in the train…
- ✓ Ad applications

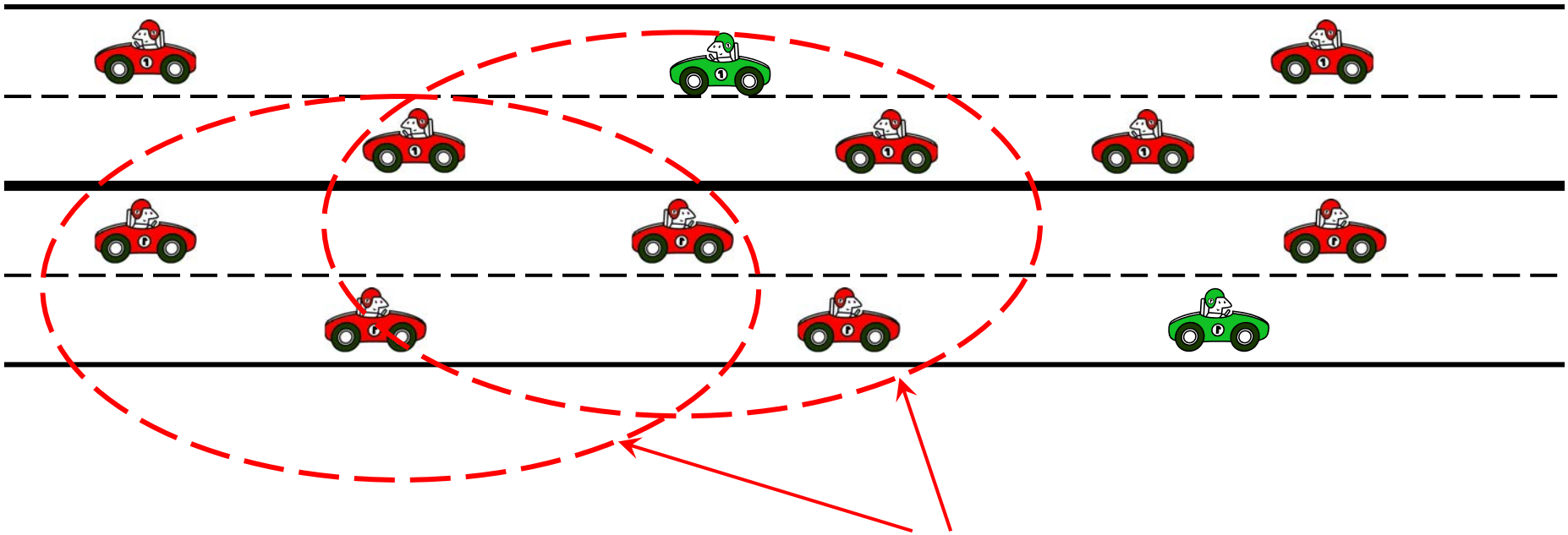
Real Situation: Variation and Diversity of Scenarios

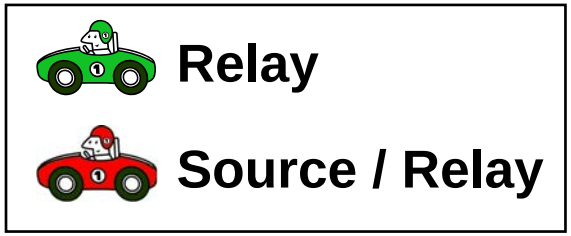




- ✓ Density: average
- ✓ *Few* sources: *little* new injected traffic

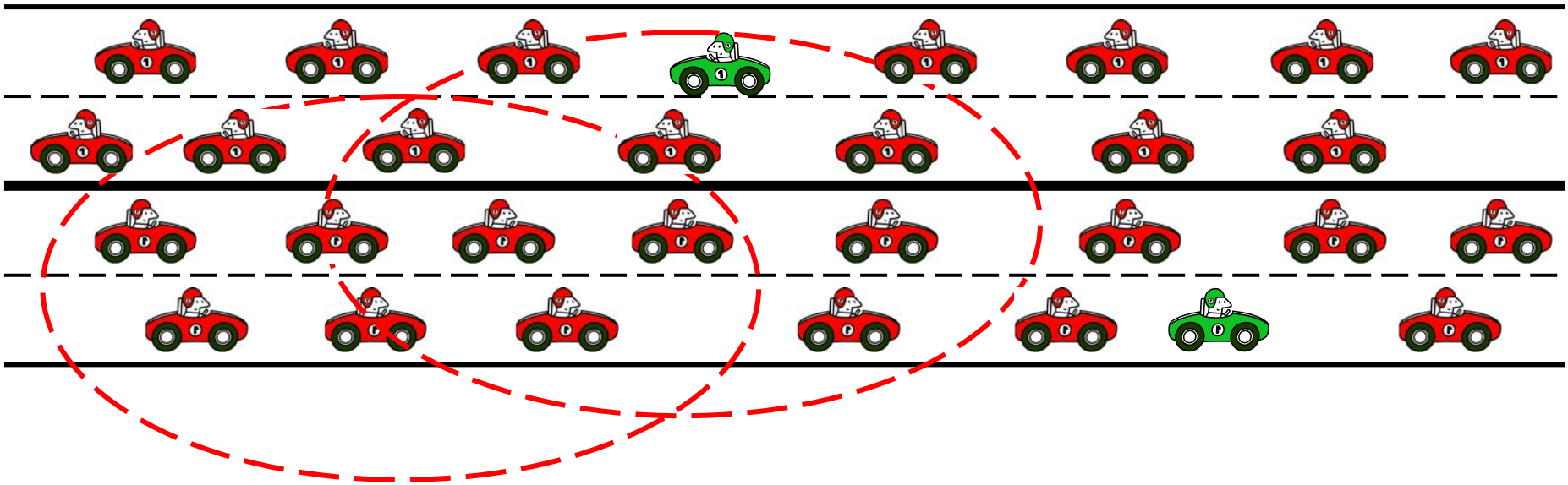
Real Situation: Variation and Diversity of Scenarios

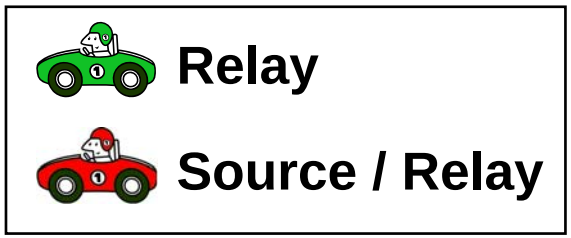




- ✓ Density: average
- ✓ *almost all* are sources: *a lot* of new injected traffic

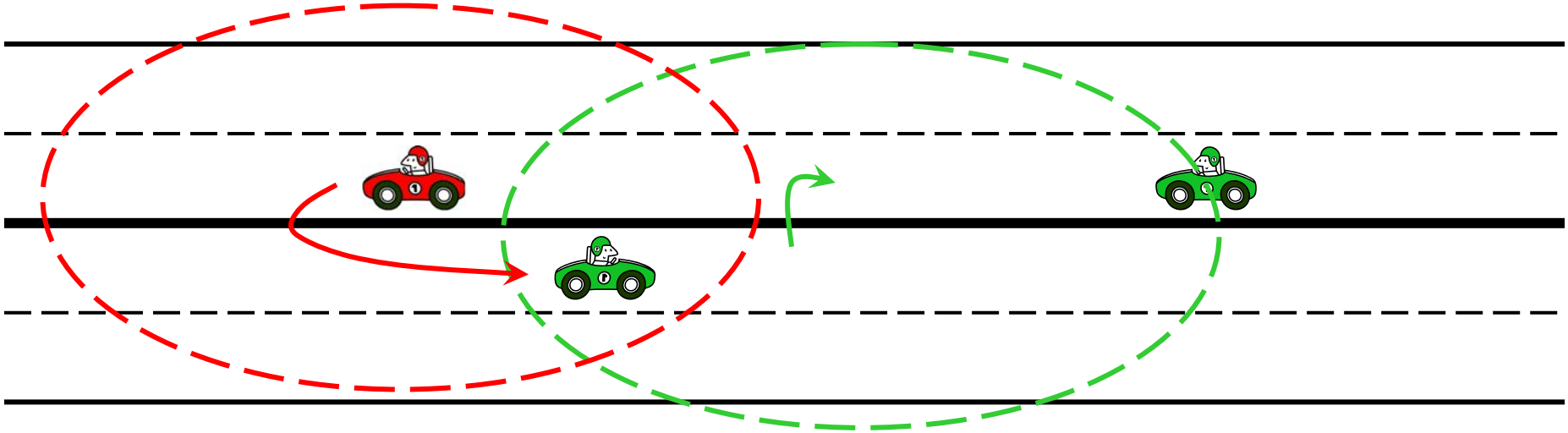
Real Situation: Variation and Diversity of Scenarios





- ✓ Very high density (traffic jam)
- ✓ *almost all* are sources: *a huge amount* of new injected traffic
- ✓ One hop: *+ 200 neighbors*

Real Situation: Variation and Diversity of Scenarios



- ✓ Density: very sparse.
- ✓ No communication without *mobility* (opportunistic communication)

An autonomic mechanism for multi-hop broadcast that adapts to this diversity in scenarios is a must, otherwise network failure

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- Introduction
- **SLEF Middleware : Self Limiting Epidemic Forwarding**
- Performance Validation
- SLEF vs. K-Hop broadcast
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SLEF: Self Limiting Epidemic Forwarding

- We propose a Multi-hop broadcast *Middleware* for *Ad Hoc* networks.
- We call it SLEF: Self Limiting Epidemic Forwarding
  - ✓ Nodes forward each packet they receive with a given probability called *Forwarding Factor*.
  - ✓ Packets are forwarded within a *limited* hop-count.
- Features:
  - ✓ *Autonomic:* Adapts itself to any change in the network.
  - ✓ *Complete middleware*
  - ✓ Does not need / exchange *any topology information*. Uses only local information to the node (very short contact time).

SLEF is designed to hold in *all* scenarios, in particular in *very dense* and *very sparse* ones

Essential Functions for Multi-Hop Broadcast

SLEF implements ***6 essential functions*** needed with any multi-hop broadcast

1. **Congestion control:** first mechanism proposed for broadcast in ad hoc networks

2. **Efficient use of MAC broadcast**:
   - ✓ 802.11 broadcast does not implement any exclusion mechanism (RTS/CTS) and it performs poorly (similar to Aloha). We replace it by a new scheme that we call ***pseudo-broadcast***.
   - ✓ 802.11 broadcast does not implement Ack. Pkts might be transmitted in the vacuum. We implement a ***presence indicator*** that does not need any message exchange.

3. **Scheduler / fairness:** A ***scheduler*** is needed to decide which packet to serve. It is based on Source ID to ensure some level of ***fairness***.

4. **Buffer management:** responsible of cleaning the buffer in order to keep space for new incoming pkts.

5. **Spread control**

6. **Inhibition**

Spread Control: Adaptive TTL

Why: Trade-Off Spread vs. Application Rate

Spread: number of nodes that receive a packet.

$$\lambda = \frac{R_0}{1 + FF * N}$$

N : Spread

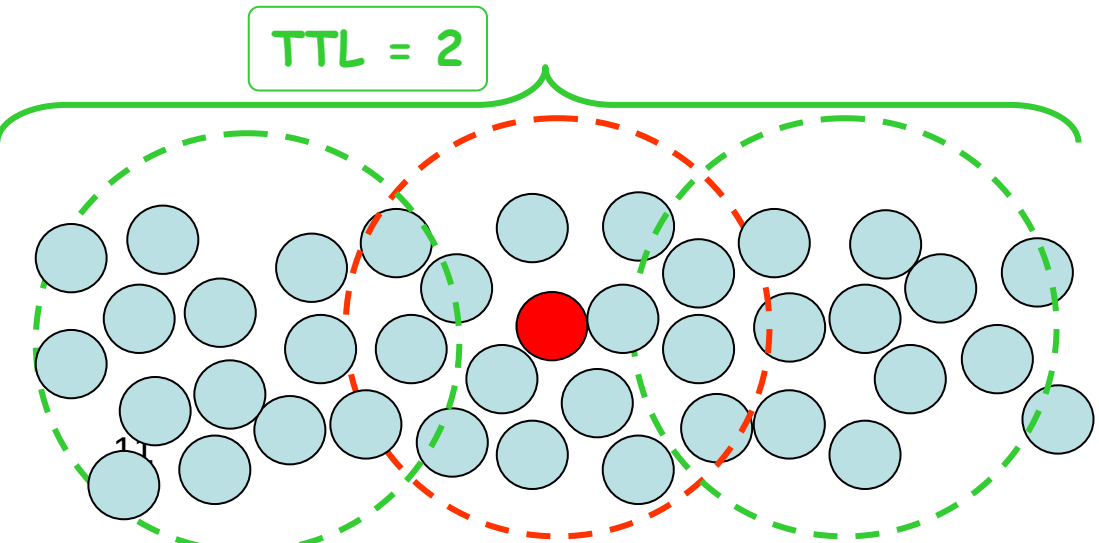
FF: Forwarding Factor

R0: Nominal Rate of MAC Layer

λ : Application Rate

How:

- We use an ***Aging*** mechanism
- ***Adaptive TTL:*** Aging ***adapts locally*** the ***TTL*** to the different network setting, based on the ***send/receive events.***
- The idea is as follows:



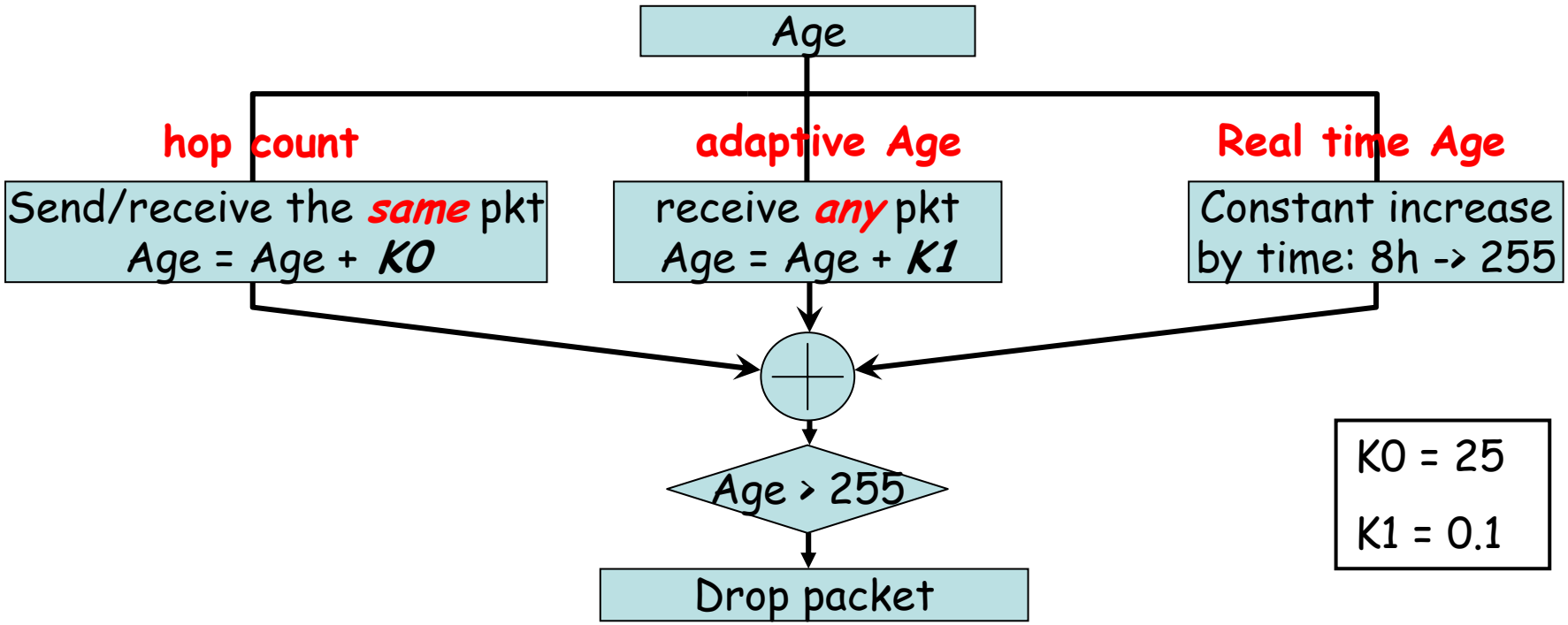
✓ Density ↗ => Spread ↗ with fixed TTL: Rate ↘

✓ Density/rate ↗ =>TTL ↘ : In a traffic jam: TTL = 1

✓ Density/rate ↘ => TTL ↗: In a very sparse network: TTL = 10

Aging

- ✓ New created pkt: Age = 0
- ✓ Pkt received for the same time: ***Age = 255 – TTL***
- ✓ Age manipulated locally.
- ✓ when transmitting: ***TTL = 255 -Age***



✓ ***Hop count:*** plays the role of a fixed TTL (=255/K0) if the network is not congested.

✓***Adaptive Age:*** adapts the TTL to the network activity, which reflects the density and the traffic load

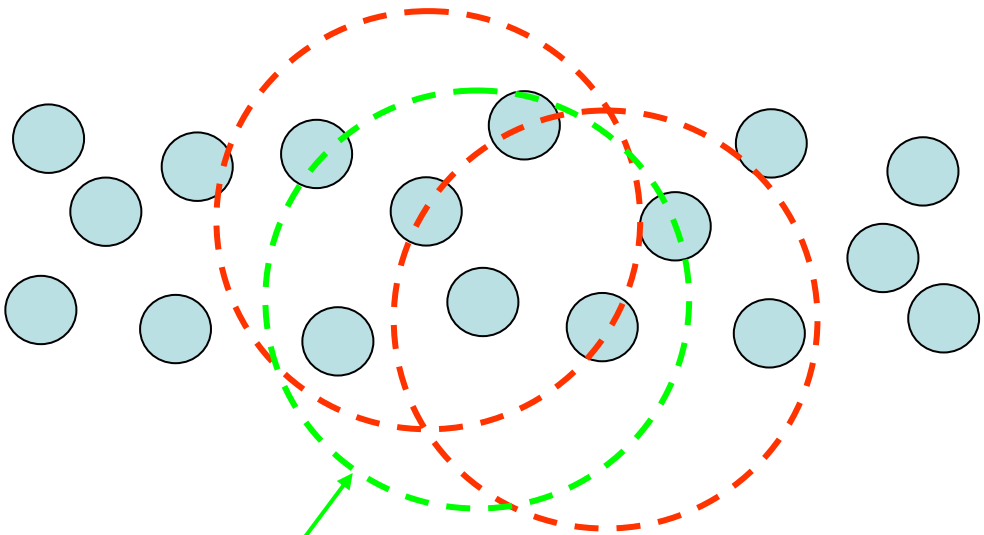
✓***Real time Age:*** A pkt lives at most 8 hours (work cycle).

Inhibition

➡ **Why:** To Minimize redundancy (save resources)

➡ **How:**

- ***Inhibit*** nodes from transmitting ***over sent/received*** pkts.
- We compute a ***virtual rate*** for each packet based on the ***send/receive*** events.
- ***Adaptive Inhibition:*** the virtual rate ***Adapts locally*** the ***Forwarding Factor*** to the different network settings



Transmission would be redundant

One send/receive event

Two send/receive events:

The green nodes are ***inhibited:*** smaller forwarding factor

Virtual Rate

- ***Virtual Rate:*** The max rate a packet is transmitted with
- For each send / receive event on a given pkt:

1- The virtual rate is computed as follows:

$$\texttt{vRate} \leftarrow R_0 a^{\texttt{rcvCount}} \; b^{\texttt{sendCount}}$$

RO : nominal MAC rate [pkts/s]
RcvCount : number of times the pkt is received
SendCount : number of times the pkt is sent
a and ***b*** : are coefficient less than 1: ***a=0.1, b=0.01***

2- vRate ***decreases exponentially*** with send/receive events.

3- The pkt is allowed to be transmitted only after: current time + $\frac{1}{\texttt{vRate}}$

The smaller the vRate is, the longer the time a pkt has to wait is: The pkt might be dropped before being transmitted

- Unlike other inhibition mechanisms, the virtual rate based inhibition allows transmitting the pkt ***multiple times*** if needed.

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Setting

Scenarios:

- Vehicular networks.
- Different network settings: node density, traffic load…

Network Simulator: JIST-SWANS, A JAVA simulator for Ad Hoc networks

Vehicular Mobility Simulator: STRAW, an extension of JIST-SWANS. It provides a mobility model based on the operation of the real vehicular traffic.

Topo : 2-lanes road, speed limit 80Km/h

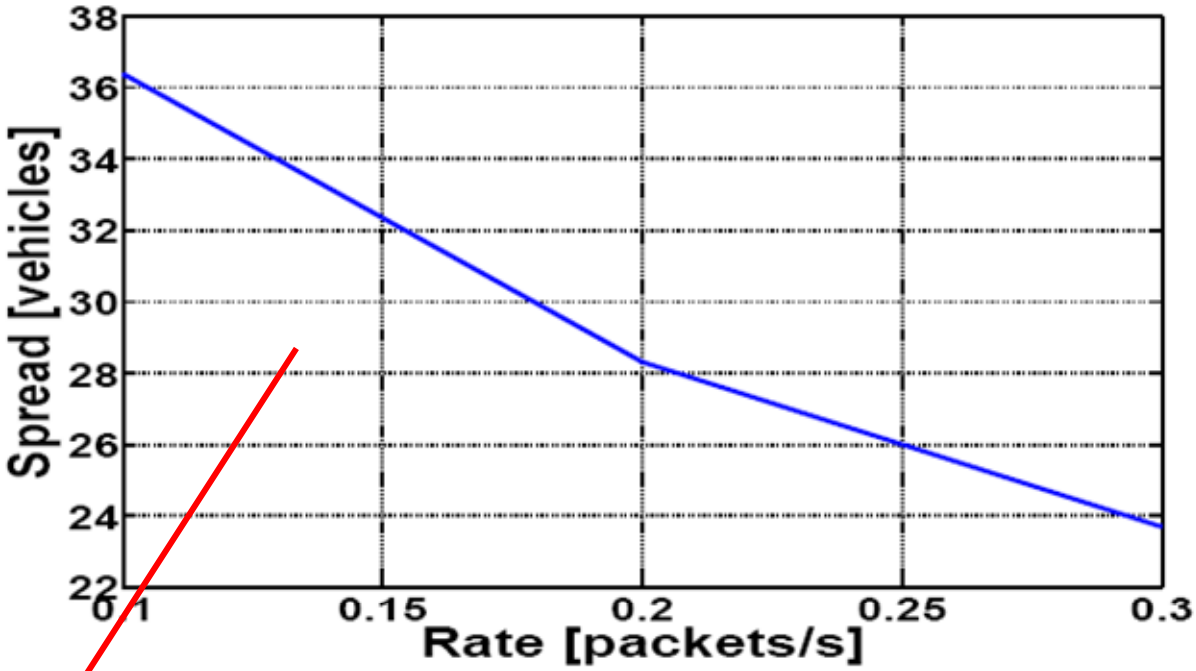
MAC : 802.11/b

Channel : Fading

Range : 300 m in average

Adaptation of the Spread to the Rate

Density: 12 vehicles/Km

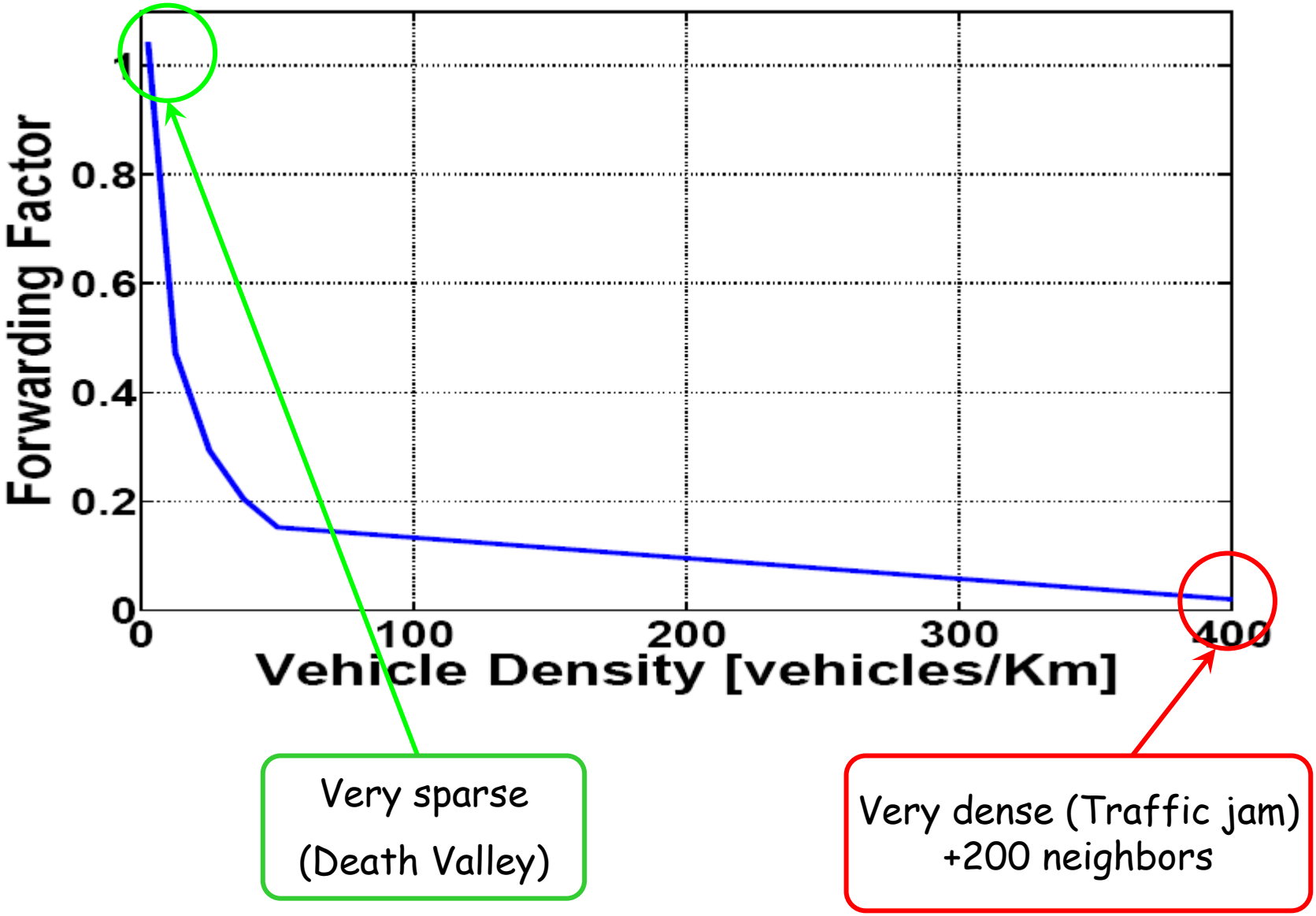


Adaptive TTL

$$\lambda = \frac{R_0}{1 + FF * N}$$

Rate ↗ ⇨ Spread ↘

Adaptation of the Forwarding Factor to the Density



Importance of the Pseudo-Broadcast

Very dense (Traffic jam): +200 neighbors

	Normal broadcast	Pseudo-broadcast
Channel utilization	0.02	0.7

Table 1: Channel utilization in a traffic jam.

Idea: implement a ***mutual exclusion*** mechanism for ***broadcast*** in order to avoid ***collision***

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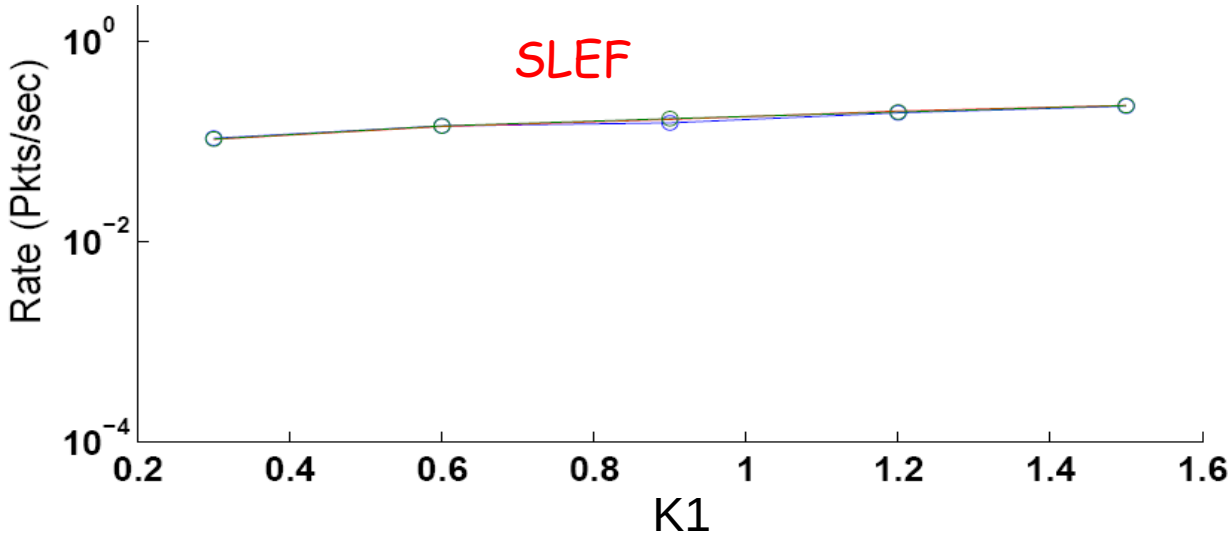
K-Hop Broadcast fails if not Adjusted

Very dense (traffic jam): +200 neighbors

TTL = 1

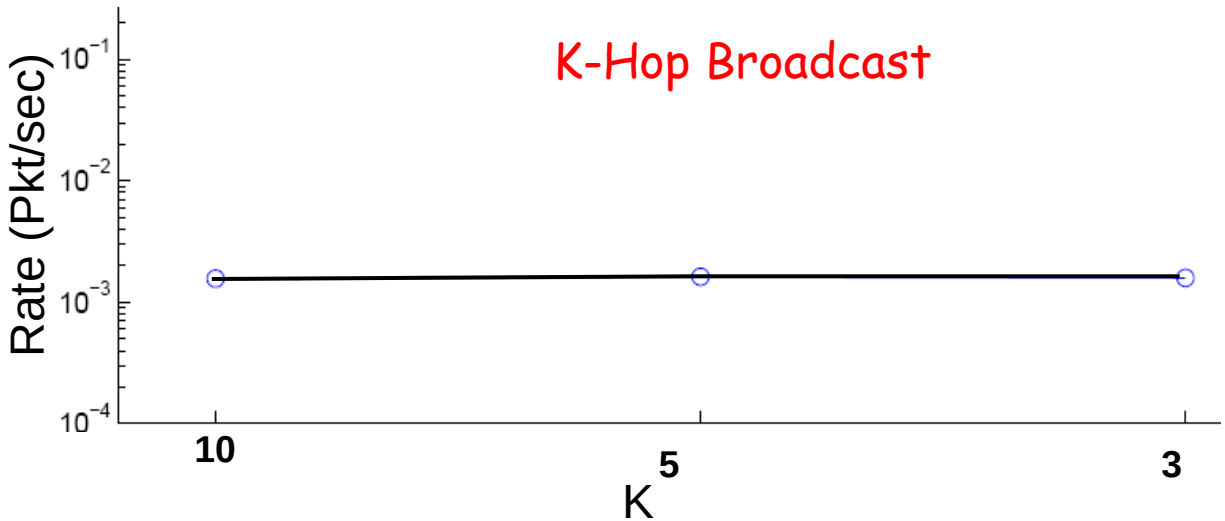
Self adjusted



With ***SLEF***, the rate is ***100 times*** larger than with ***K-hop broadcast***

TTL = K

Congestion collapse



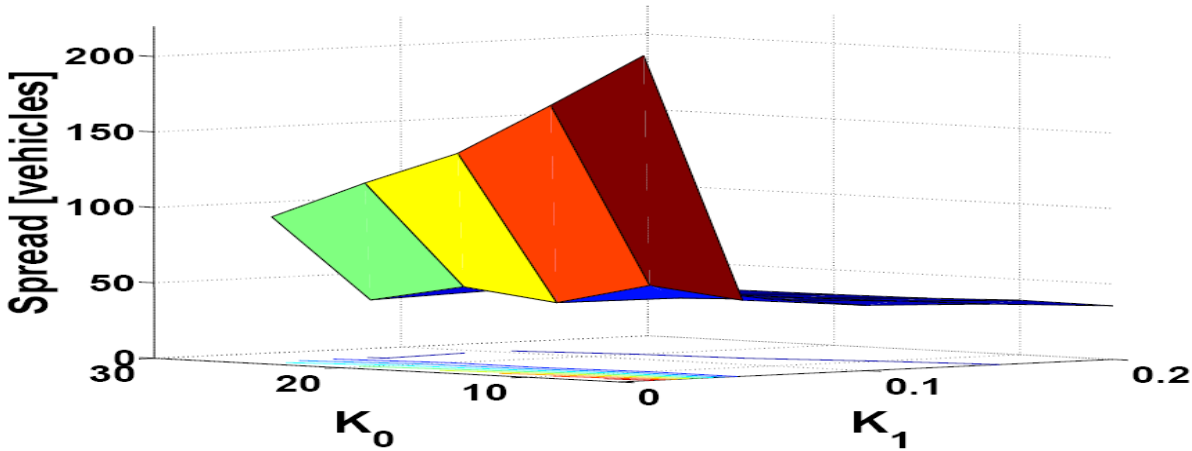
K-Hop Broadcast Needs to Adjust K for each Scenario

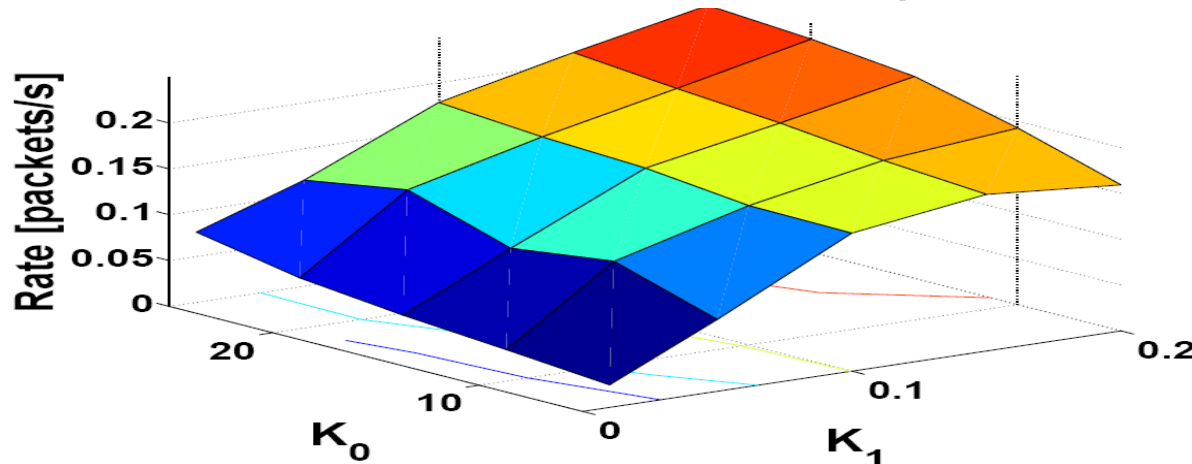
SLEF	K-Hop Broadcast
✓ 2 parameters to adjust: K0, K1	✓ 1 parameters to adjust: K
✓ Once Adjusted, they work well with all settings	✓ Needs to adjust whenever the network setting (density, traffic load, mobility,…) changes

Adjusting the ***spread-rate balance*** according to the application needs

Default values for K0 and K1 are computed in the paper

$$\lambda = \frac{R_0}{1 + FF * N}$$





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Conclusions

- We propose SLEF: a Multi-hop broadcast middleware for ad hoc networks
- SLEF Features:
  - ✓ ***Autonomic:*** Adapts itself to any change in the network.
  - ✓ ***Complete middleware***
  - ✓ Does not need/exchange ***any topology information***. Uses only local information to the node.
  - ✓ Works even in extreme scenarios (very dense/sparse…)
- SLEF addresses ***new issues*** and solves them, such issues are ***congestion control in broadcast mode in ad hoc network*** and ***spread-rate balance***.

SLEF **is a replacement of** ***K-hop broadcast, SLEF*** **works well in all circumstances**

The End

MERCI DE VOTRE ATTENTION