Ring-based forwarder selection to improve packet delivery in ultra-dense networks

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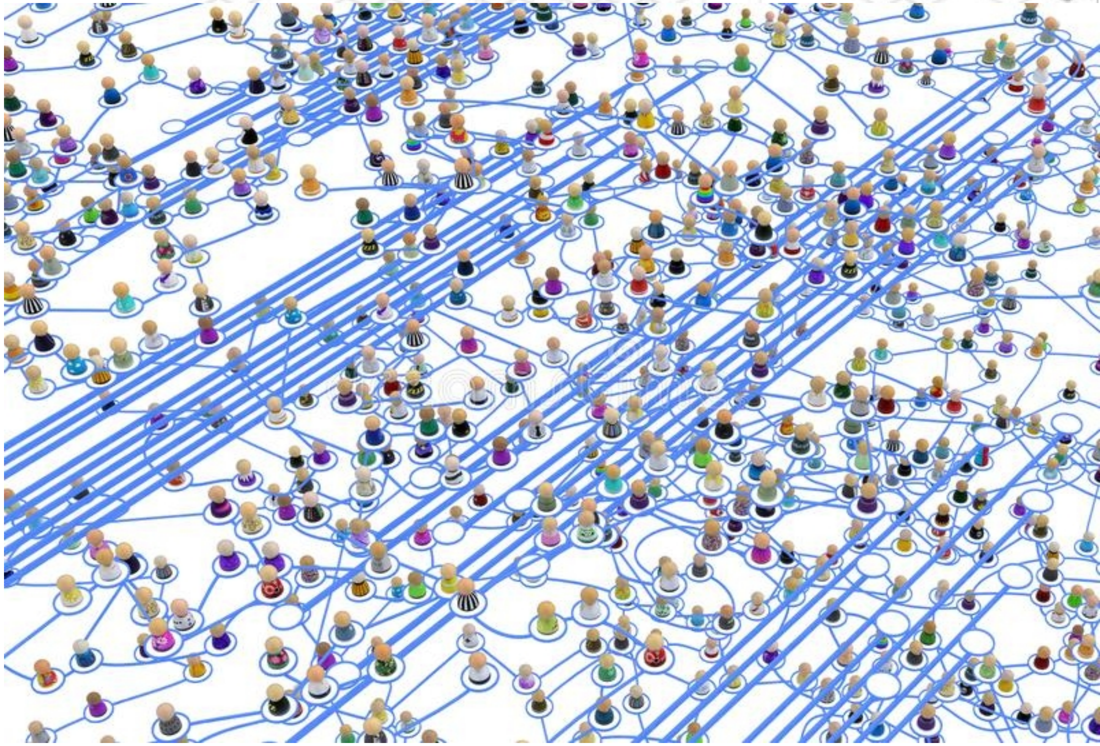
Ultra-dense ad-hoc wireless networks:

Network **densification** is the key to Internet of Things (**IoT**) growth.

- Large network size
- High local density



Challenge 1: How to efficiently route a message from one point to another in ultra-dense networks?

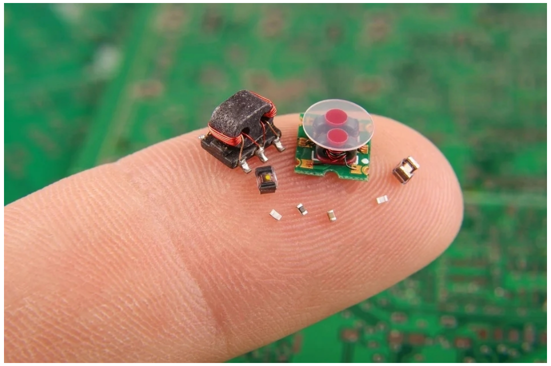
Electromagnetic nanonetworks:

Nanonetworks are ultra-dense ad-hoc wireless networks of **sensors** at the nanoscale.

Nanotechnology could reengineer us!

- **In body communication:**
  - COVID-19 mRNA vaccines (lipid nanoparticles)
  - Cancer-detecting nanosensors (future)

- **Software-defined metamaterials**
- **Wireless robotic materials**
- **On-chip communication**



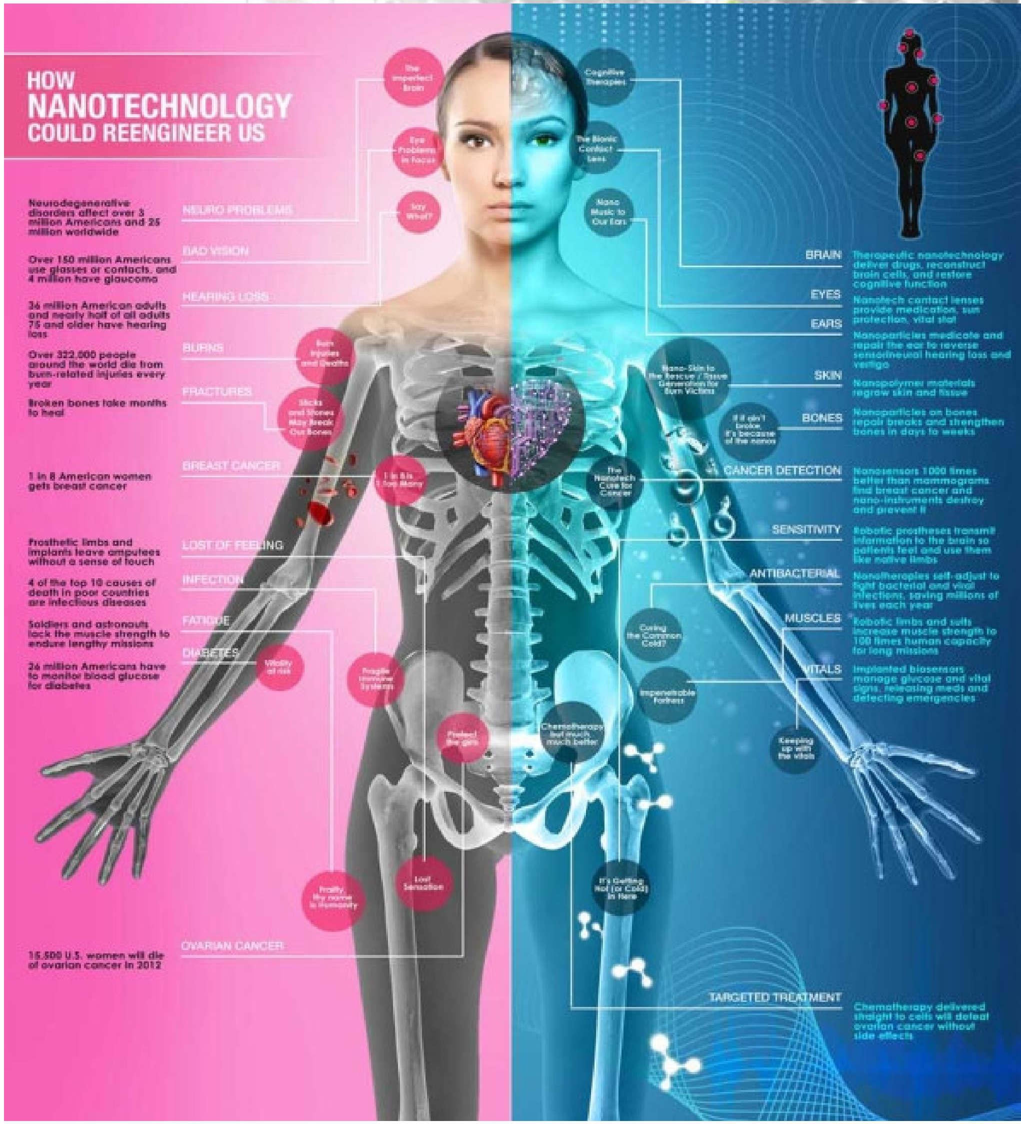
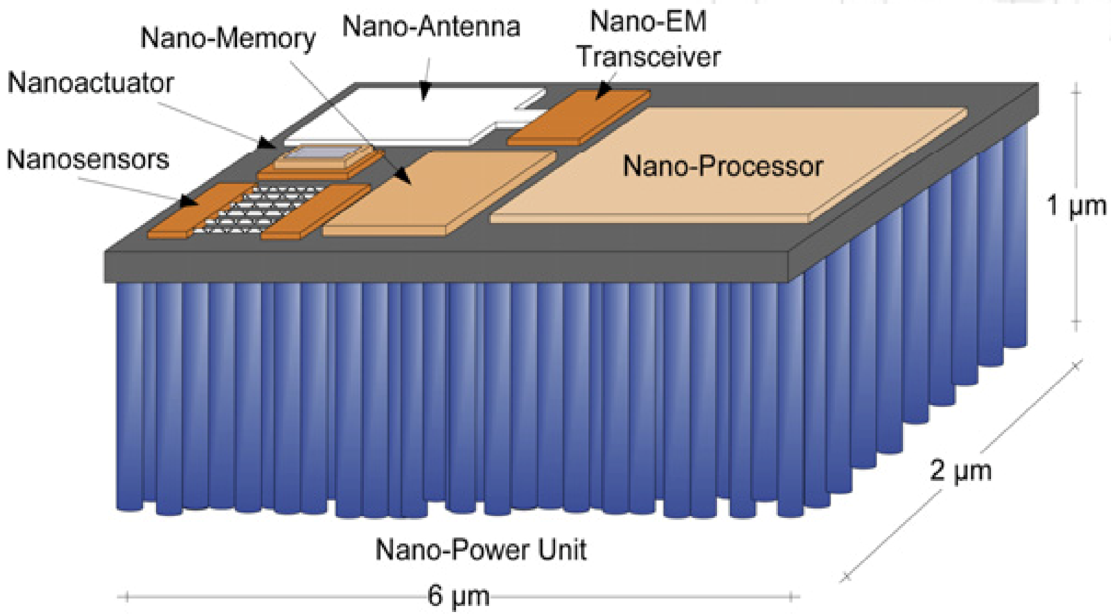


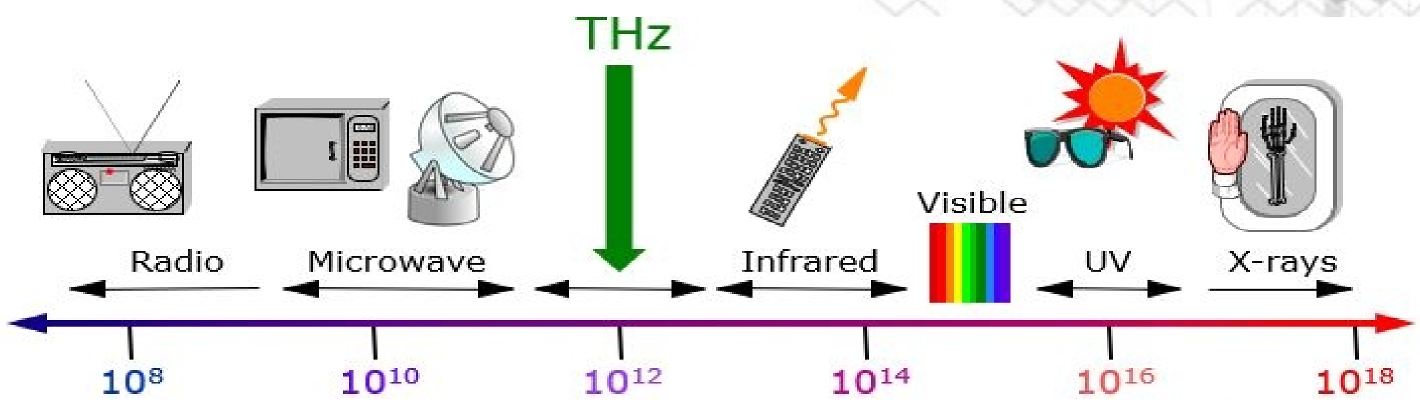
Photo credit :Ben Schiller. Fast Company.

Electromagnetic nanonetworks:



Challenge 2: tiny size nanosensors → drastic constraints on memory, energy and CPU

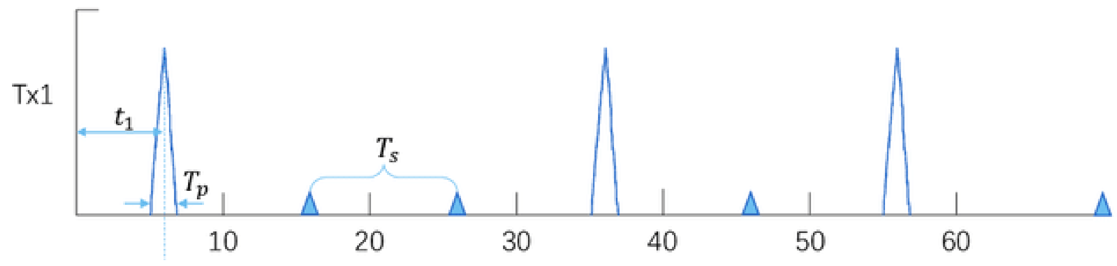
New communication paradigm for electromagnetic nanonetworks:



Communication in the **terahertz frequency** band (0.1–10 THz) using **graphene** antennas.

TS-OOK modulation (Time Spread On-Off Keying): (pulses and not signals with carriers)

- Bit~1: pulse (energy)
- Bit~0: silence (no energy)

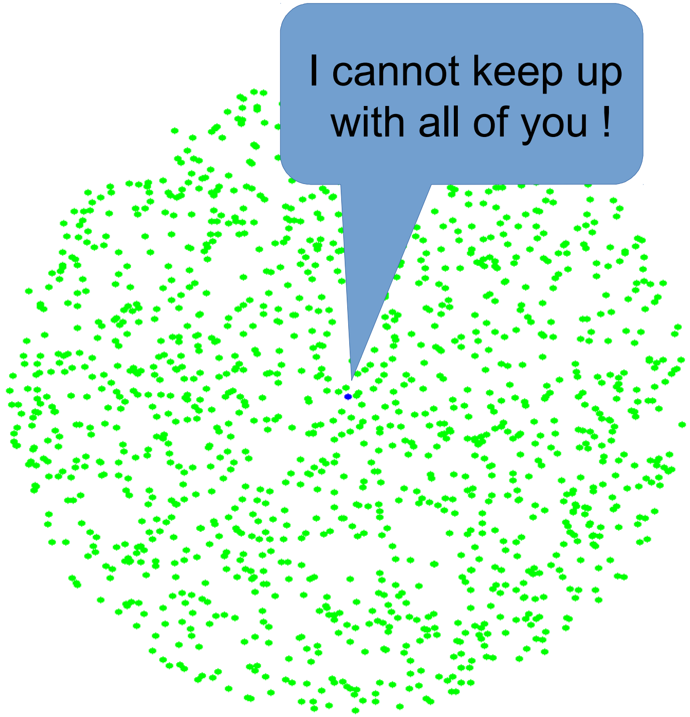


Challenge: How to route in (resource-constrained) ultra-dense networks?

<u>Goal:</u> **Scale-up** existing routing protocols in multi-hop communications.

Taking into account:

- Large **neighborhood**
- **Incapacity of a node** to retain full neighborhood or network knowledge
- **Unavailability of location information** (no GPS nor RSSI etc.)



Proposed work: Ring-based forwarder selection to improve packet delivery in ultra-dense networks

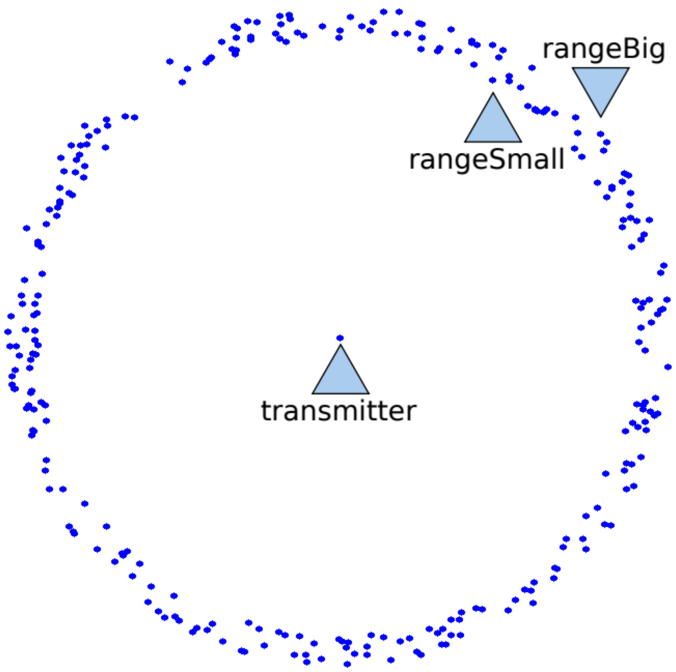
<u>MAC-level ring implementation above existing routing protocols:</u>

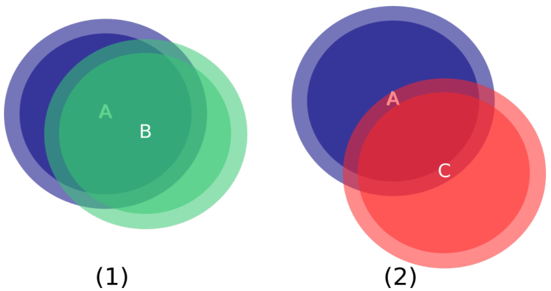
- Each **forwarder** (transmitter) sends **two high-power and low-power control packets**, only **once** before the very first data packet transmission (in static conditions).

- The nodes that **receive the high-power control packet and not the low-power control packet** are in the **ring** area.

- **Forwarders** are the nodes **selected by the routing** protocol **AND** are in the **ring** area near the communication range.

<u>Expectation:</u> reduction in the number of forwarders and thus an <u>**increase in network performance**</u>.





Making C forward achieves more forwarding progress than B femto-st SCIENCES & TECHNOLOGIES

Ring simulations:

Bitsimulator: A scalable electromagnetic nanonetworks simulator

A **source** node generates a CBR flow of packets to:

1) **Broadcast** it to the **whole network** in the first simulation (backoff flooding).
2) **Send** it to a **destination node** in the second simulation (SLR).

- **Shadowing** propagation model
- **TS-OOK** modulation

Scenario

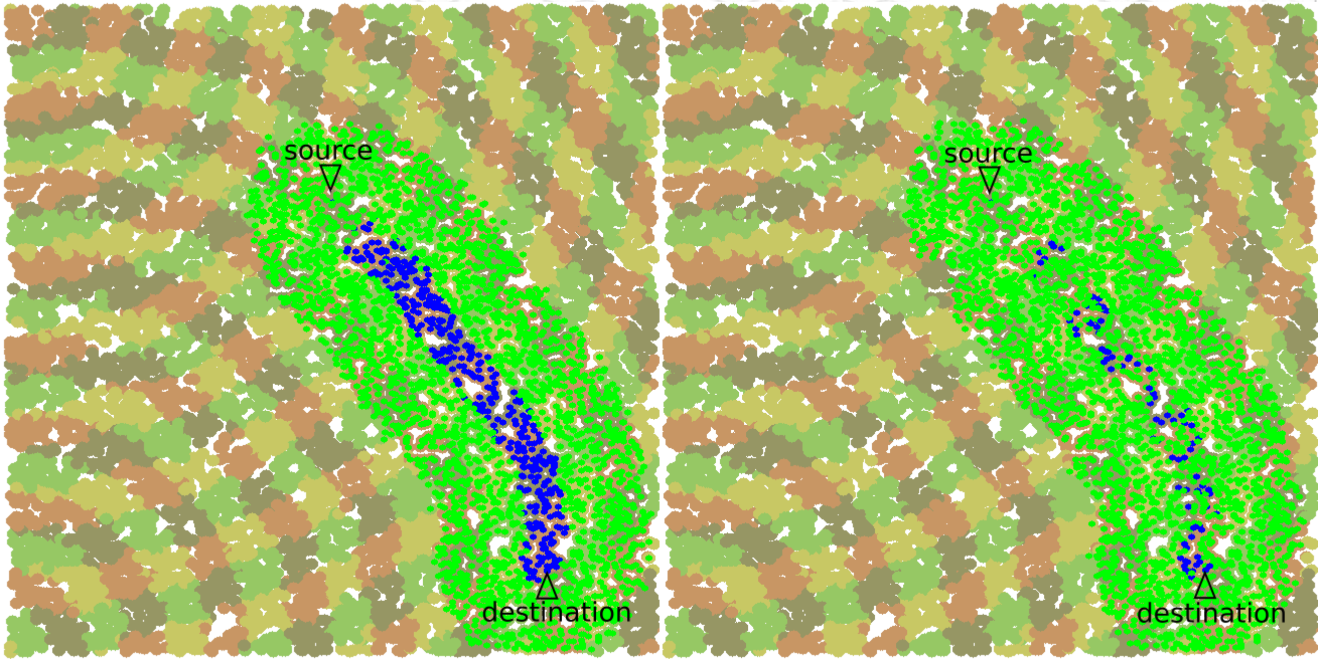
parameter	value
Size of simulated area	6 mm * 6 mm
Number of nodes	10 000, 20 000
Communication range = RangeBig	900 µm
RangeSmall	800 µm
Average number of neighbors per node	408 for 10 000, 819 for 20 000 nodes
Data packet size	1 003 bit
Control packets size	101, 102 bit

http://eugen.dedu.free.fr/bitsimulator/

Ring implementation in efficient routing protocols for nanonetworks:

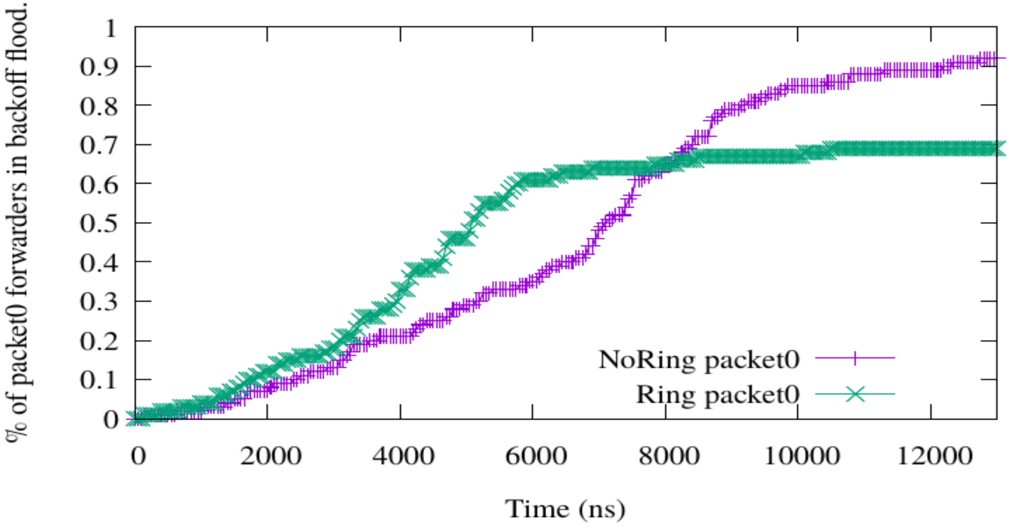
- **Backoff flooding** is a **broacasting** scheme.
  - Nodes that receive **less than *N* copies** of the data packet in a time window are **forwarders**.

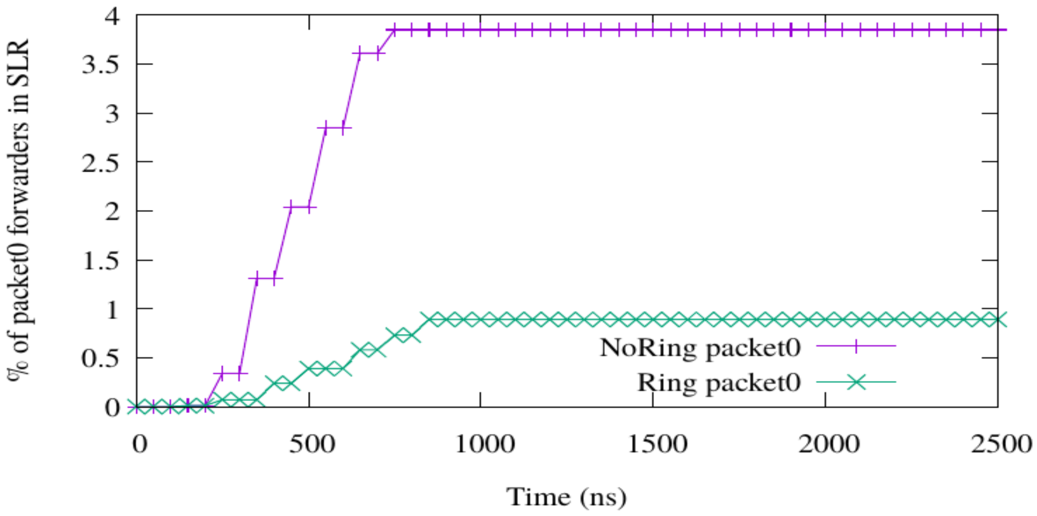
- **SLR** (Stateless Linear-path Routing) is an addressing and **unicast** routing scheme.
  - Network is divided into zones using a **coordinate** system of **hop counts** from anchors.
  - Nodes that are on a line **between the source and the destination** are **forwarders**.



SLR without ring (left), SLR with ring (right)
SLR with ring uses fewer forwarders

Ring efficiency:





- Average delivery ratio is giving 1 or close to 1 values = **ring guarantees delivery** while **reducing** the number of **forwarders**

- The **ring benefit** increases with **network density**.

Reduction in number of forwarders	10 000 nodes	20 000 nodes
Backoff flooding	28%	29%
SLR	79%	82%

Results averaged for 10 packets and over 10 runs with different node positions

Ring cost:

Network traffic?

Reduction of forwarders (= reduction of packets generated) outweighs by far the additional size (**bits**) of control packets,

Ring reduces the network traffic: by 19% in backoff flooding and 77% in SLR (for 10000 nodes).

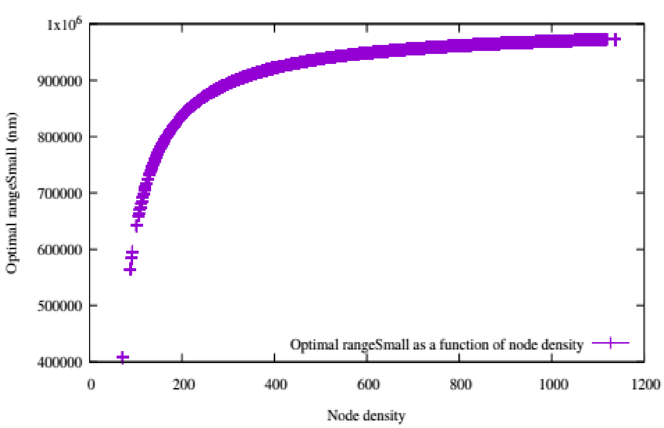
Transmission Delay?

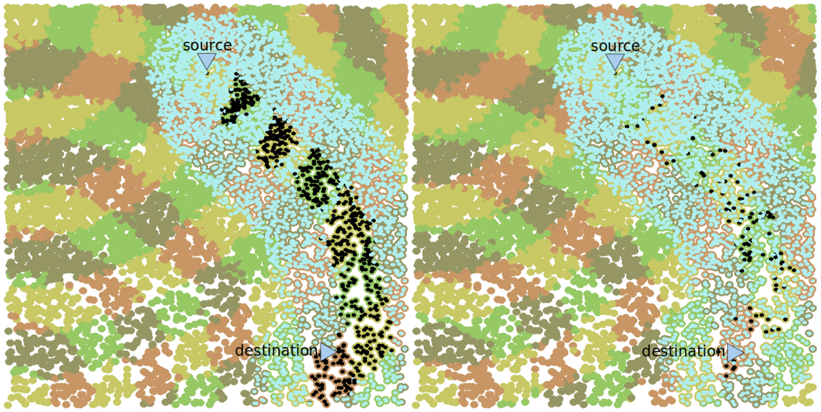
The two controls may add an **additional small transmission delay only for the first** packet generated by nodes.

Conclusion

- We presented the **ring-based forwarder selection** in a multi-hop transmission to improve packet delivery in **ultra-dense** networks.
- The ring **scales-up** routing protocols and achieves higher network performance.

Since the submission, we have improved the ring and made it **dynamically** select its width according to node density in **heterogeneous** networks.





I had the pleasure to present you our work
Thank you for this conference