Congestion Control by Deviation Routing in Electromagnetic Nanonetworks

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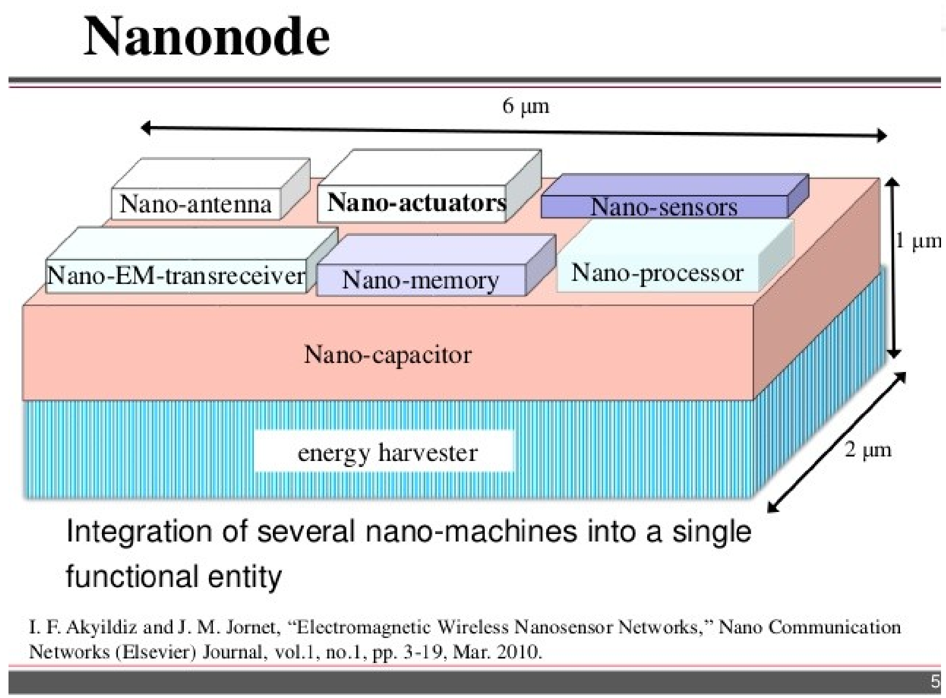
THz wireless nanonetworks

- Small communication range: ~cm
  => Need multi-hop for longer comm distances

- Nanonodes have not yet been built because of technological challenges
  => Need to develop simulation tools

- Nanodes have unusual characteristics:
  - specific modulation (TS-OOK)
  - specific collisions
  - ...

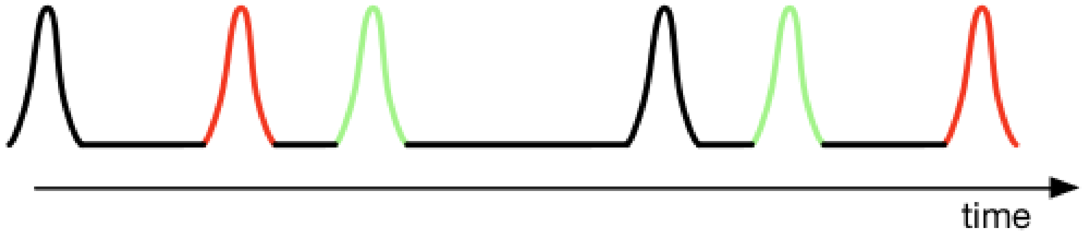


Complete machine of µm size

TS-OOK

- To send bits ”1” sender sends pulse, while for bits ”0” a silence is used
  Pulses are very short (e.g. ~100 femtoseconds)

- Pulses from a given frame are spread over a period much bigger than the pulse duration (e.g. 1000 times longer)
  This high spreading ratio allows the interleaving of frames from different communications



- Given adequate hardware resources (buffers, but also cpu or other elements), a node can be receiving several (here 3) frames at the same time.

- Individual bits do not carry sender identification information by themselves. All incoming bit have to be stored at least until complete headers have been received.

Reception buffers

- Due to fabrication constraints, those hardware resources are limited.

  => This limits the number of simultaneous frame that a node can follow.

  A node will be basically unaware of any new packets arriving when all *reception* resources are in use, and consequently lose them - even in the absence of collision.

  This is different from traditional routers were frames are sequentially received by interfaces and can only be lost if the *transmissions* buffers are full. In that case, routers are aware of the packet drop.

- Using a simple counter, we consider that nodes are aware of the number of receptions buffer currently in use

Congestion definition

Knowing the maximum number of buffer and the number of reception buffers currently in use, we can compute the node congestion level C at time t

$$C(t) = Rn(t) / Rmax$$

with Rn the number of reception buffers in use at time t and Rmax the total number of buffers available on the node

Congestion Thresholds

We now define two congestion thresholds :

- Upper threshold Cu : node is congested and measure should be taken

- Lower threshold Cl: node is not congested any more, back to the normal behaviour

Those two thresholds can be equals and hence behave as a unique threshold femto-st SCIENCES & TECHNOLOGIES

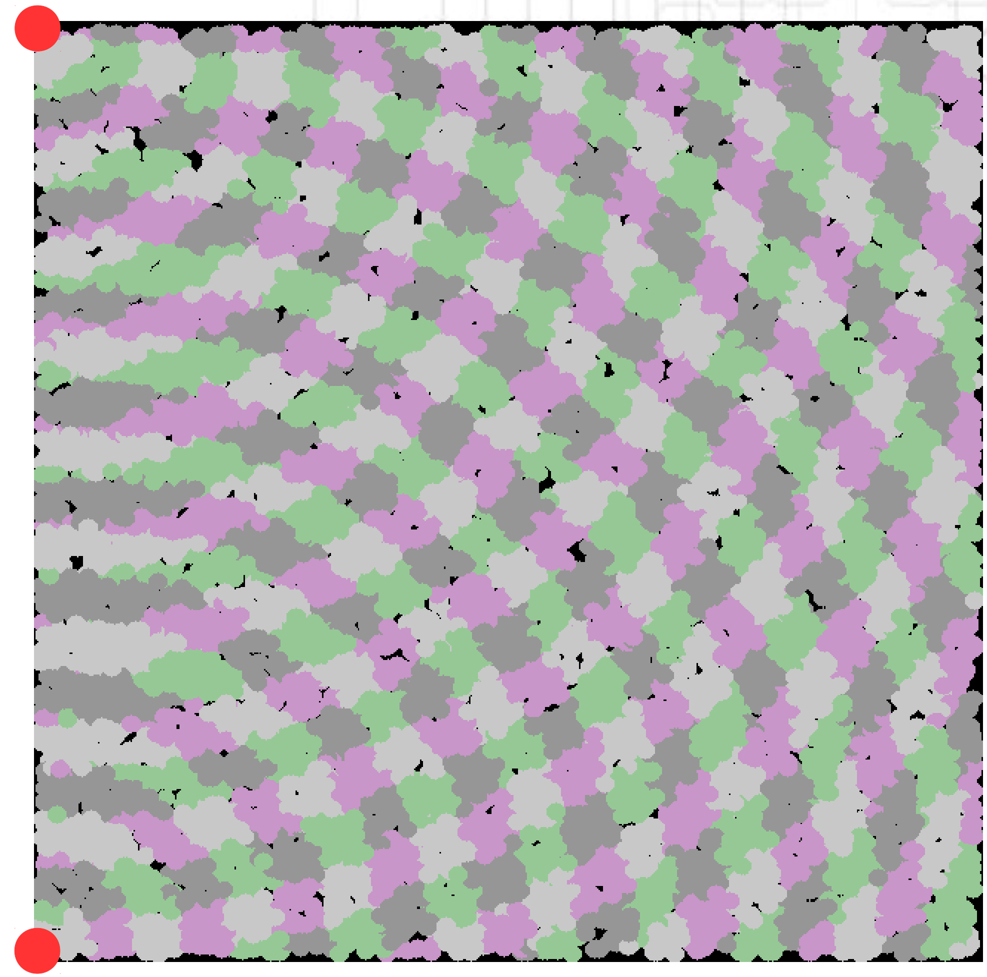
SLR addressing

Beaconing anchors

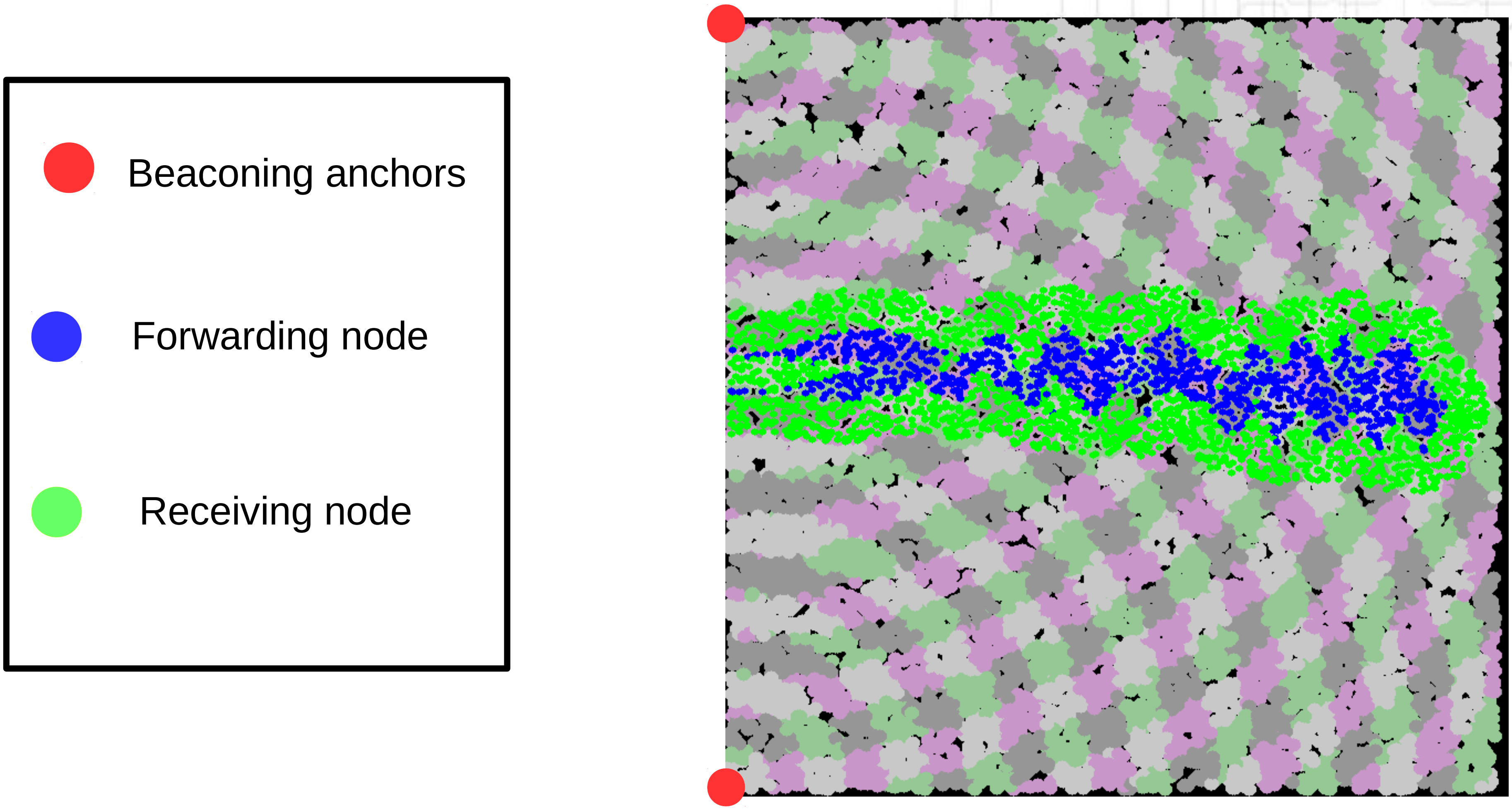
Every anchor broadcast a beacon containing a counter incremented at each hop

By observing those counters, each node can know how far it is from both anchors

With adequately placed anchors, this creates a coordinate system



SLR routing



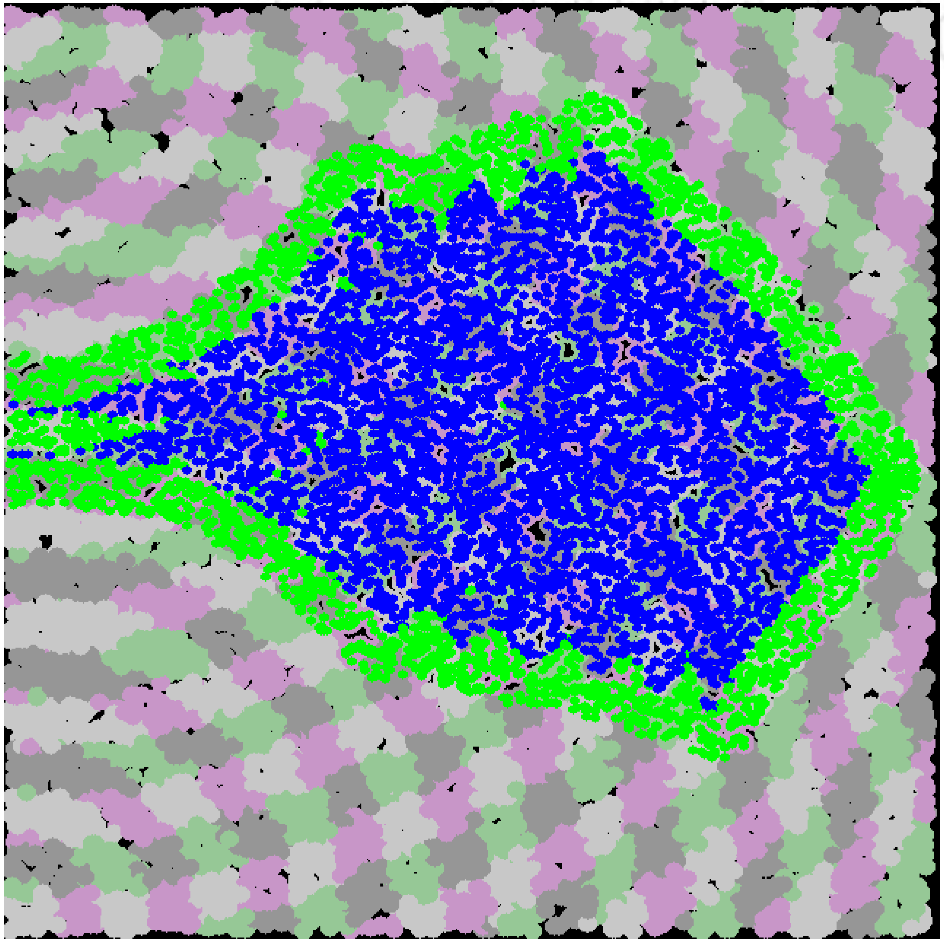
SLR path width

To increase reliability, SLR can be tuned to used a wider route

Worst for congestion : use more resources

But can be used wisely ...

```
bool isOnPath( node n,
               address src,
               address dst,
               int m) {

    return : n is on SLR path of
             width m from src to dst

}
```

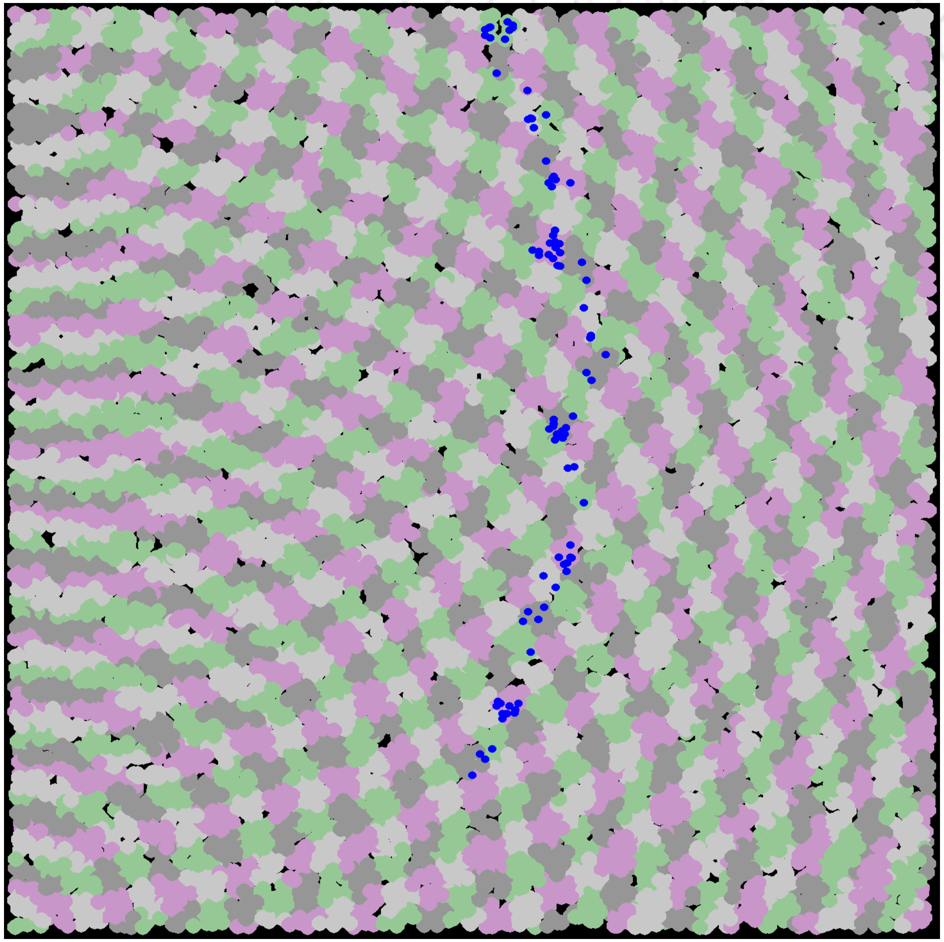


Reducing the number of forwarders

Need to reduce the number of forwarder to not detect congestion with only one message in the network

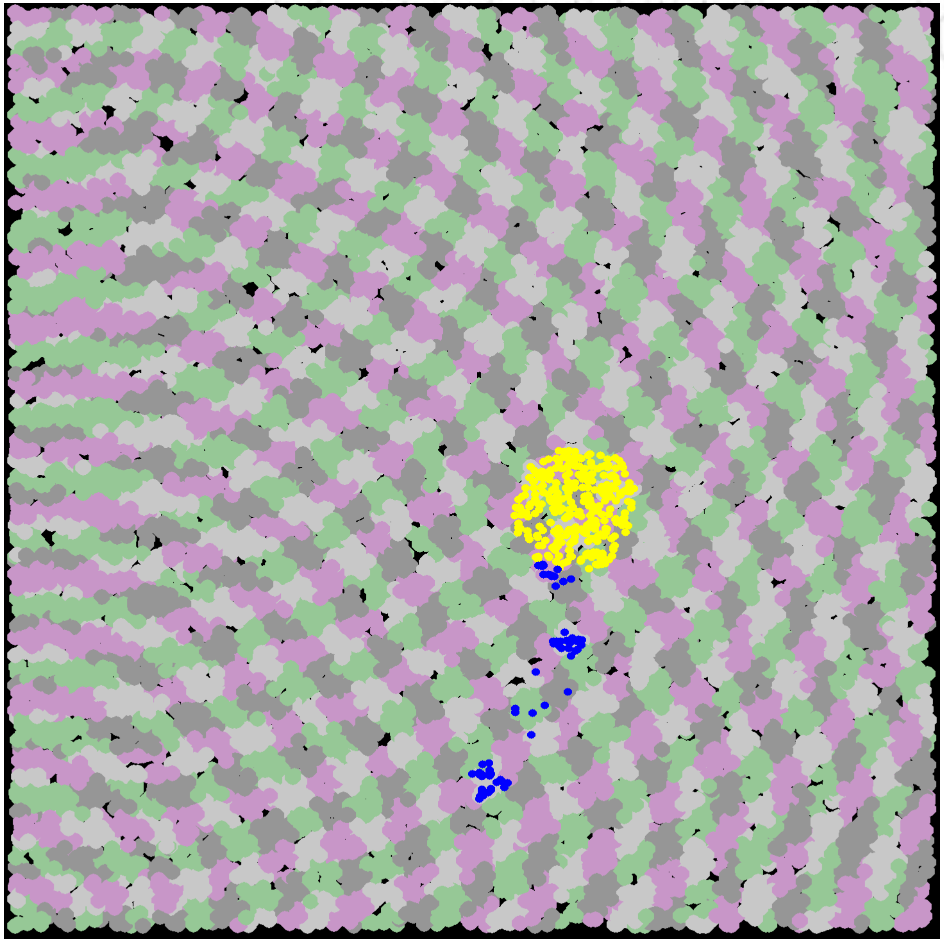
=> Random selection of the next forwarder via the backoff flooding

It’s counter based and designed to insure that the message is forwarded while keeping the number of forwarders low.



Congested area

- Wireless communications are broadcasted by nature.
- Nodes are able to handle multiple simultaneous incoming frames, but if too many senders are active at the same time, they will saturate their reception capabilities
- In this example, independent and parasitic flows are active in the yellow area. All neighboring nodes are affected.

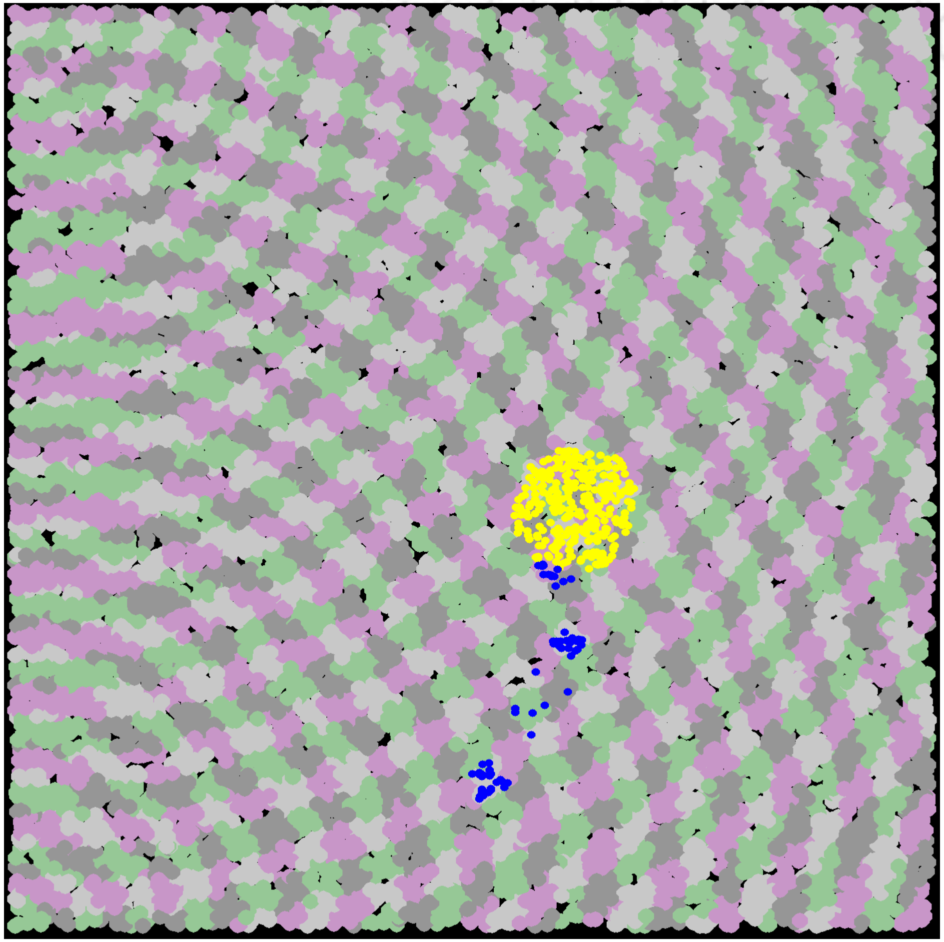


Deviation routing : Congestion blocking

Forwarding node

Congested node

Yellow nodes are completely congested, they cannot receive more packets. Node around have reached the Cu threshold due to local traffic, the prevention mechanism is triggered

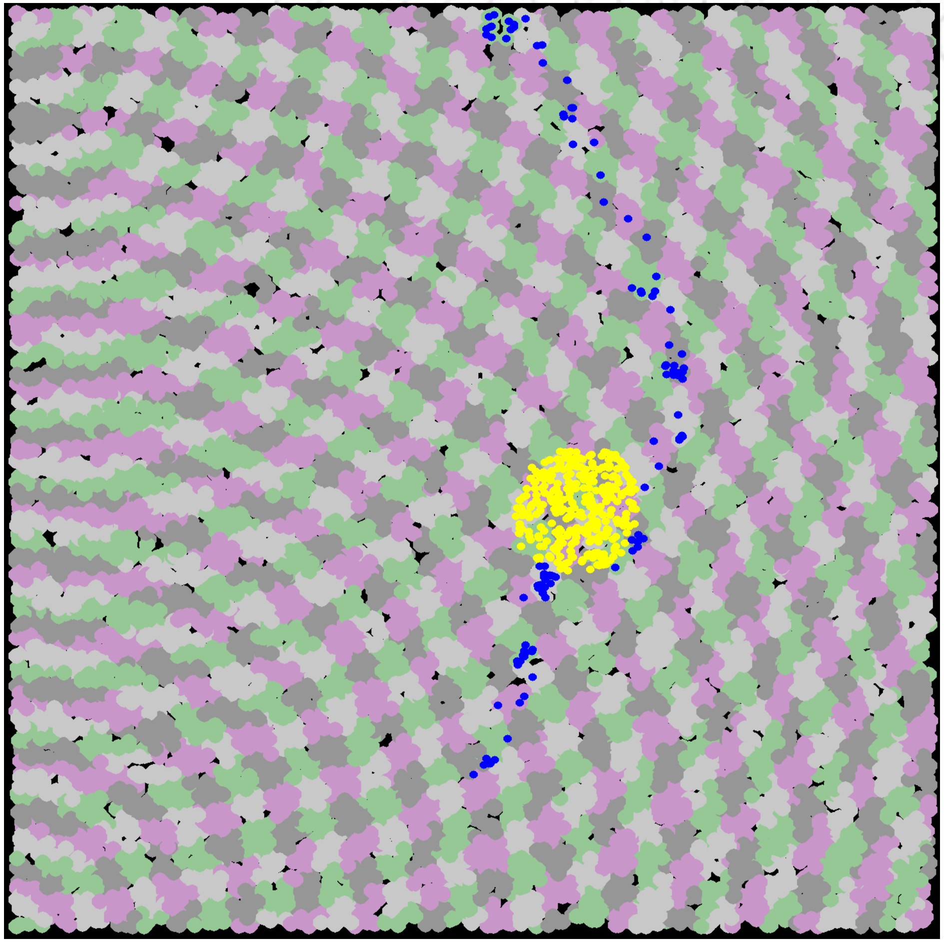


The flow cannot reach the destination because there is no resources available on yellow nodes : they cannot handle new packets

Deviation routing : Congestion avoided

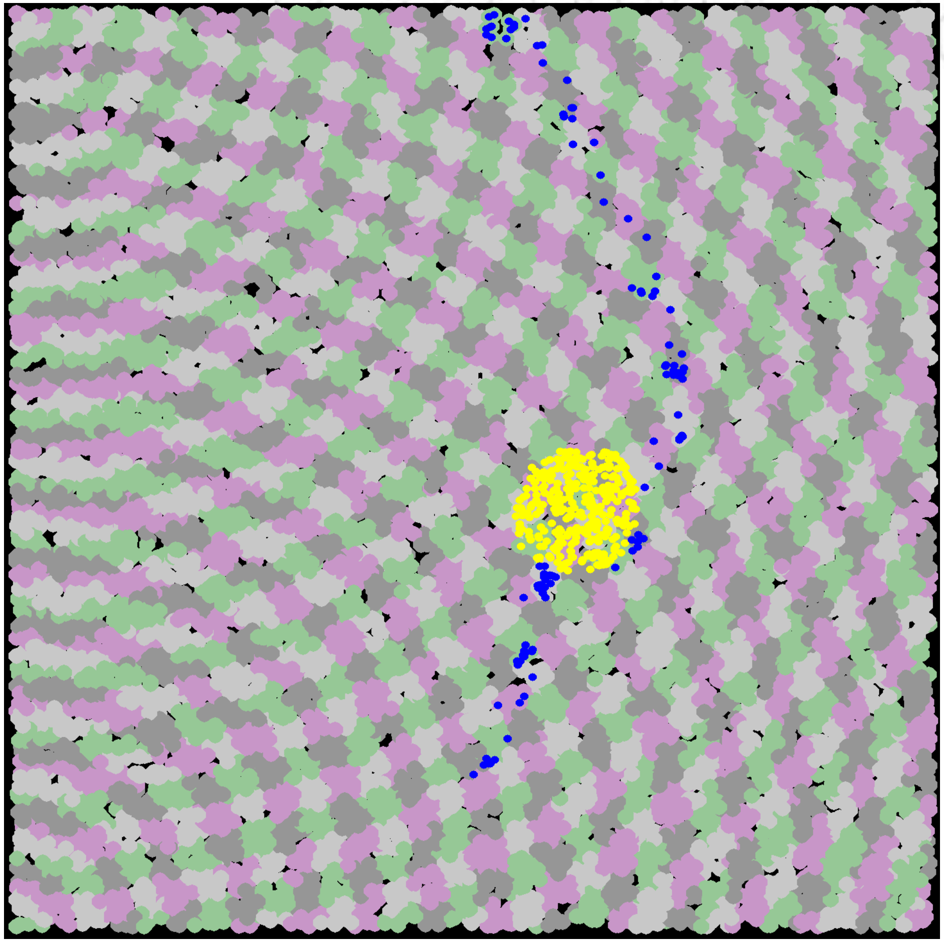
We use the capability of SLR to spatially occupy the network to create a new route and deviate from the original one

```
bool isOnPathDeviation(
                        n,
                        src,
                        dst,
                        m){

  return : isOnPath(n,src,dst,m) AND
   NOT isOnPath(n,src,dst,m-1)

}
```



Deviation routing : 3rd dimention

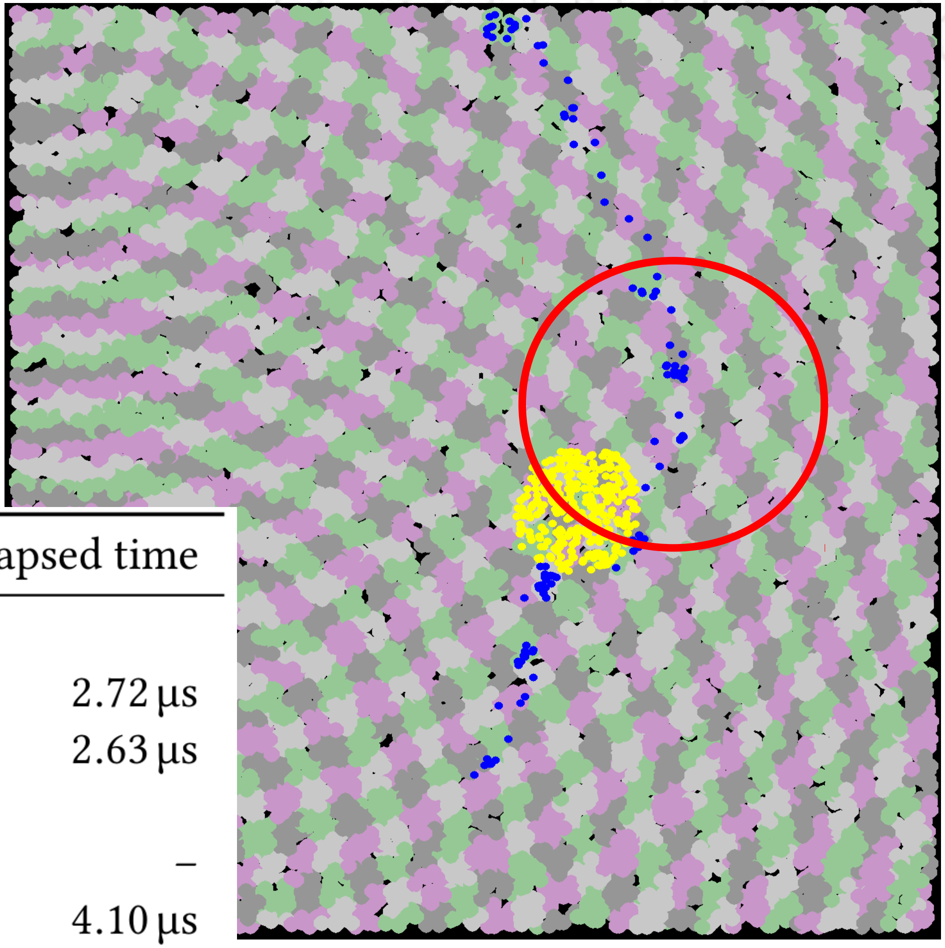
- It works in 2D networks works, but rapidly reach limits when no uncongested areas are available to deviate to.
- Many nanonetworks (for example in Programmable Matter filed) are in 3D
- In 3D, many more paths are available to deviate to, and the algorithm becomes way more relevant.



Deviation routing : Congestion avoided

Then, when the congestion gets below the CI threshold the route automatically gets back to the normal route

This congestion control mechanism acts before packet losses. It prevents packet from being dropped by using resources in another part of the network



	Avg. packets sent	Avg. elapsed time
Without congestion:		
Modified SLR	96.4	2.72 µs
Deviating SLR	87.3	2.63 µs
With congestion:		
Modified SLR	–	–
Deviating SLR	135.0	4.10 µs

Conclusion

Two contributions

Congestion detection that takes TS-OOK specificities

It can be used separately from the deviation to serve others congestion control mechanisms

Route deviation based on SLR

It can be used separately from the congestion detection (holes avoidance for instance)

Might be very powerful in 3D...

Questions ?