Assessing Traffic Flow and Using Mobility for Distributed Applications Performance Enhancement.

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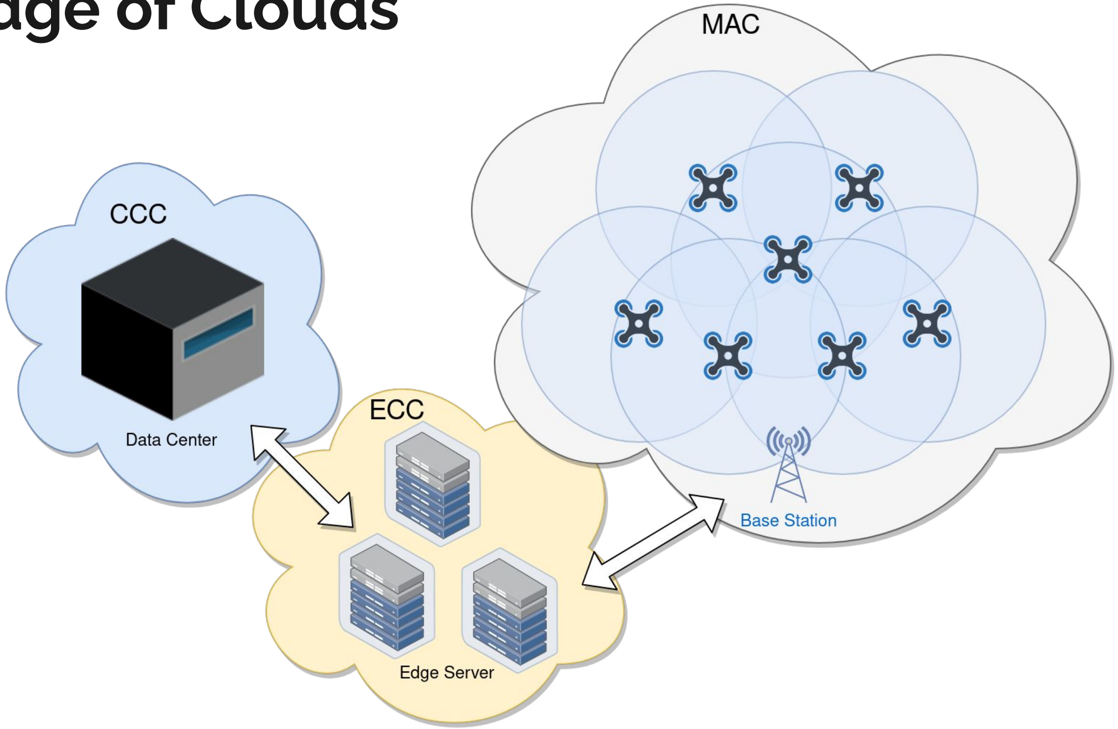
Computing at the Edge of Clouds

- Applications physically far from cloud infrastructures can benefit from closer edge servers.
- Data can be pre-processed at the edge and only processed data sent to central clouds
- Computational power at the edge can be leveraged for constrained nodes
- Improved security and privacy
- Mobile ad-hoc computing

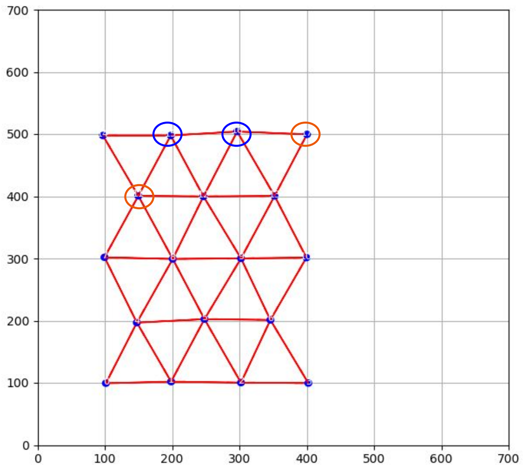


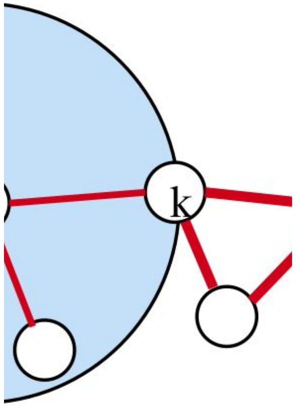
Motivation

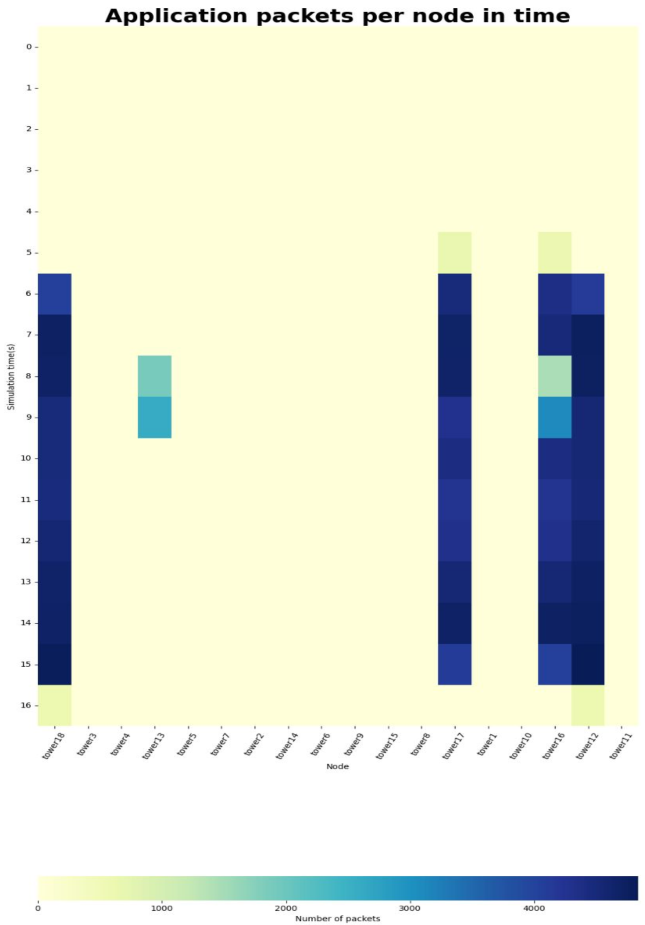
- Applications such as remote sensing and earth observation with swarms of UAVs or Satellites

- Connectivity issues of Mobile ad-hoc multihop systems
  - Unstable connections
  - Lower bandwidth
  - Channel sharing
  - MAC overhead
- Nodes are both source, destination and routers
- How the position of the nodes in the network affect the performance of the applications?

Network Model



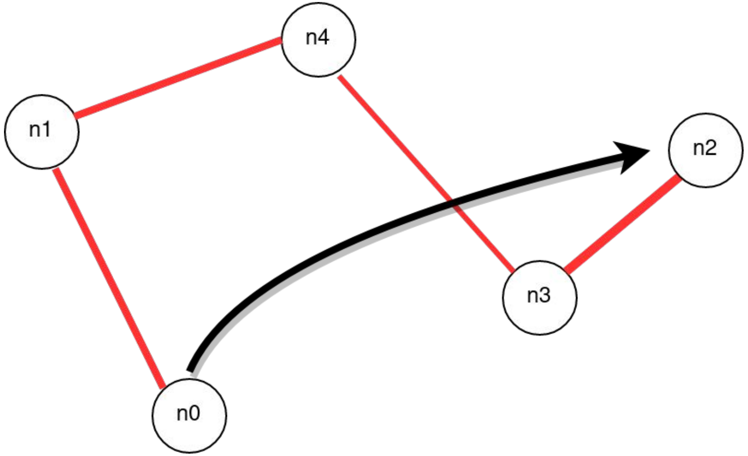




Working on the Application Layer

When we think about network congestion, it is natural to think how a routing protocol could solve that.

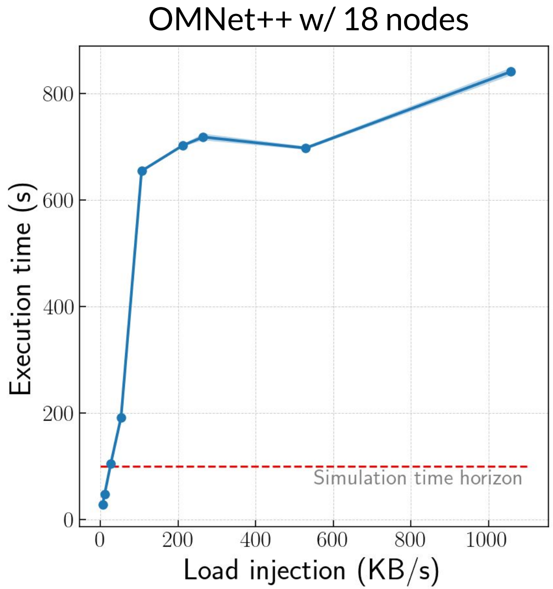
- Fragmentation of routing protocols
- Ultra specialization of protocols



Existing Tools don't Scale Well

Fine grained discrete simulations usually don't scale because they are resource hungry

- Too much memory and too much processing power to simulate each message, or packet.
- One alternative solution is too use macroscopic fluid models.



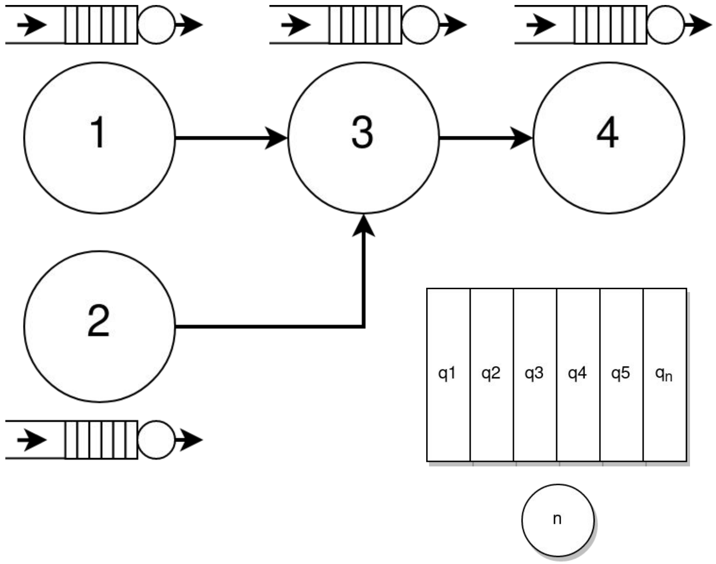
Network Model and Results

- Network Model Introduction
    - Throughput
    - Latency
- Topologies and Mobility
- Results
- Can we enhance performance by using mobility?

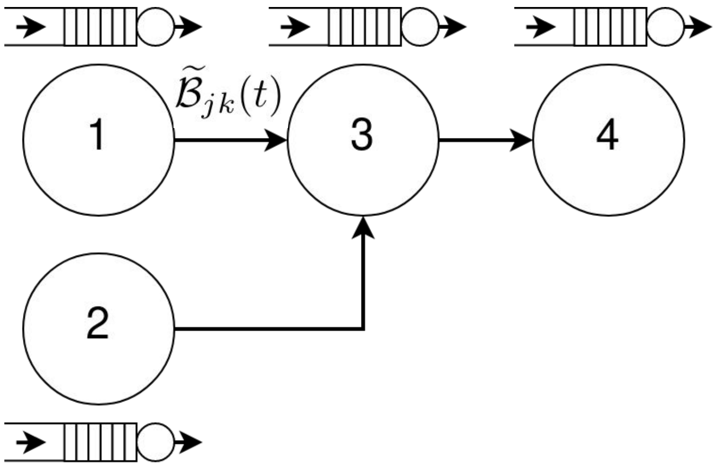
Traffic Flow Model

One ad hoc network topology can be modeled as a multi-queue system:

- For each simulation step, part of each queue leaves the node according to the amount of available bandwidth.
- The forwarded data is added to next hop's queue and moves towards the final destination.



Traffic Flow Model



Departure $$d_j^k(t) = \begin{cases} -\dfrac{\mathcal{Q}_j^k(t)}{\mathcal{Q}_j(t)}\widetilde{\mathcal{B}}_{jk}(t), & \text{if } \mathcal{Q}_j^k(t) > 0 \\ 0, & \text{otherwise} \end{cases}$$

Arrival $$\underset{e=k}{a^j(t)} = \begin{cases} \sum_{\substack{i=0 \\ i\neq j}}^{n-1} \dfrac{\mathcal{Q}_i^j(t)}{\mathcal{Q}_i(t)}\widetilde{\mathcal{B}}_{ij}(t), & \text{if } \mathcal{Q}_i^j(t) > 0 \\ 0, & \text{otherwise} \end{cases}$$

$$\mathcal{Q}'^k_j(t) = -\frac{\mathcal{Q}_j^k(t)}{\mathcal{Q}_j(t)}\widetilde{B}_{jk}(t)\mathbb{1}_{\mathcal{Q}_j^k(t)>0}\mathbb{1}_{j\neq k} + \\ + \sum_{\substack{i=0 \\ i\neq j}}^{n-1} \frac{\mathcal{Q}_i^k(t)}{\mathcal{Q}_i(t)}\widetilde{B}_{ij}(t)\mathbb{1}_{\mathcal{Q}_i^j(t)>0}\mathbb{1}_{\mathcal{R}_{i,j}(t)=j}$$

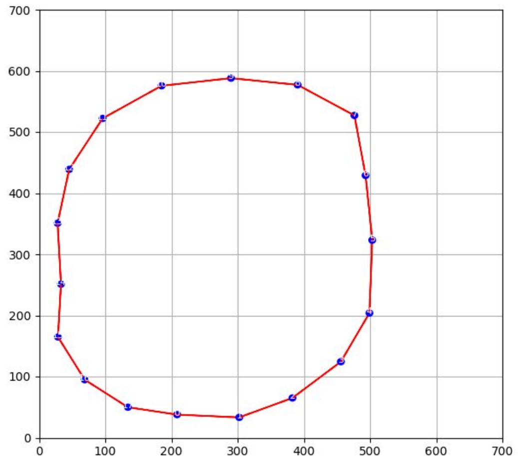
Using Average Age

As a way to model Latency

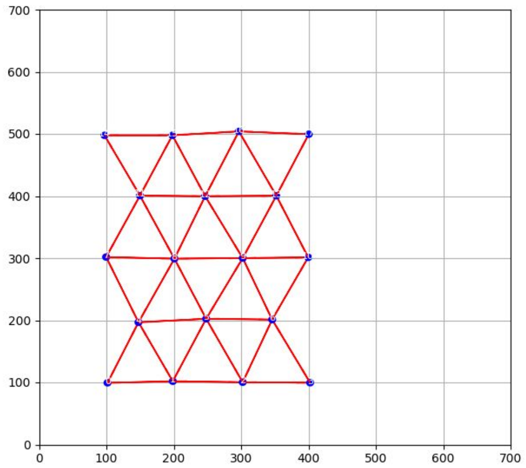
In order to model the latency of each message, conservation of momentum is used with messages' age being the conserved quantity.

$$[(\mathcal{A}_j^k(t-\delta t)+\delta t)(\mathcal{Q}_j^k(t-\delta t)-d_j^k(t-\delta t))+ \\ +\sum_{\substack{i=0\\ i\neq j\\ \mathcal{H}_i^k(t)=j}}^{n-1}(\mathcal{A}_i^k(t-\delta t)+\delta t)d_i^k(t-\delta t)]-\mathcal{A}_j^k(t)\mathcal{Q}_j^k(t)=0$$

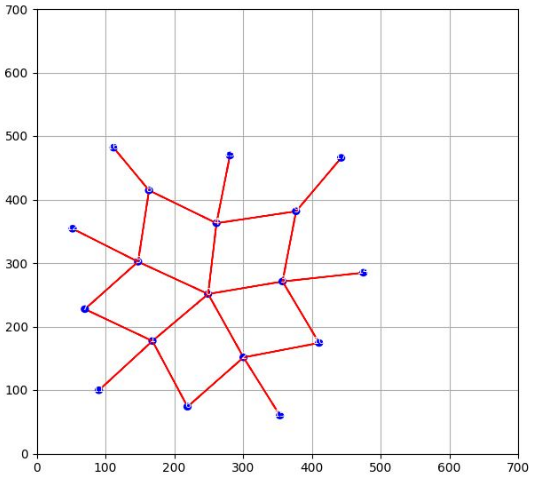
Simulated Topologies



Ring



Crystal

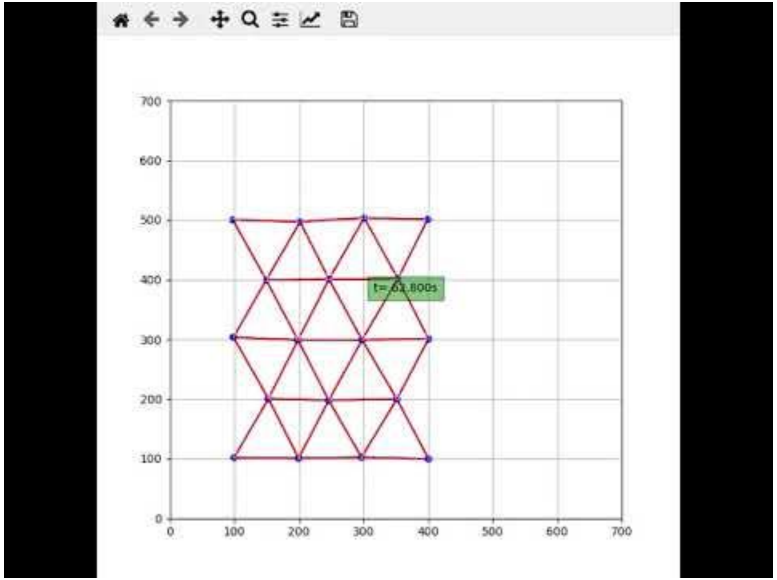


Star

Simulation Results

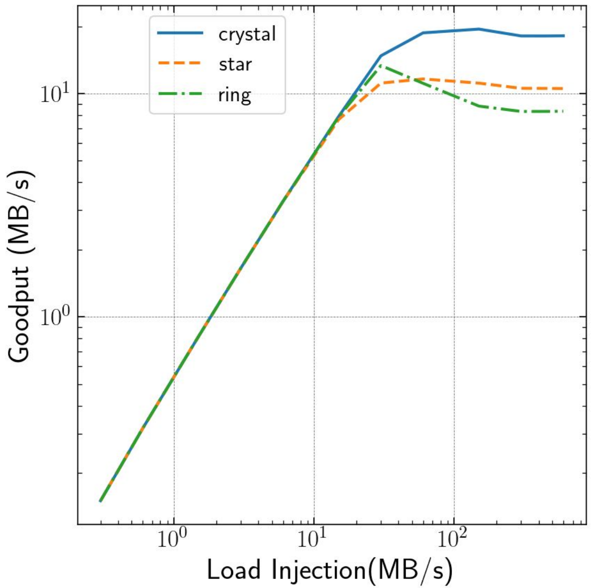
Data Injection profile

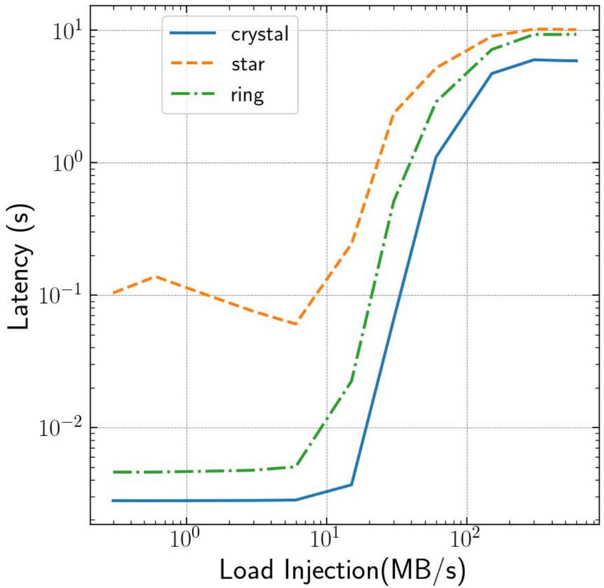
- Round Robin data injection
- f = variable, data = 3MB
- One to all sharing of equal chunks
- th = 100s



Choosing the Best Topology for the Traffic Pattern

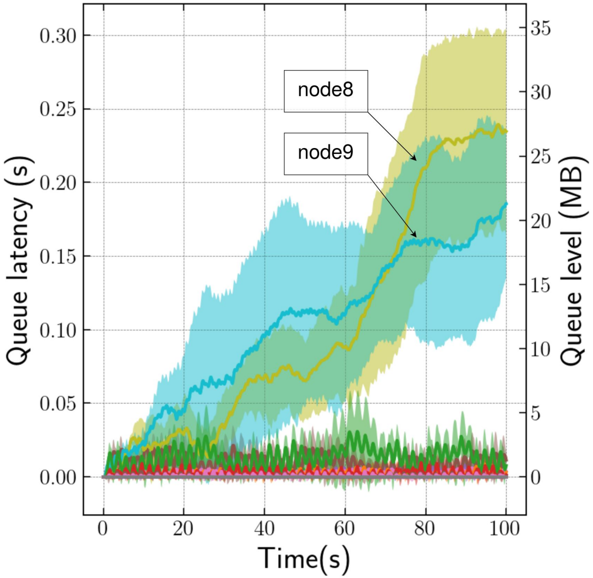
Network Saturation

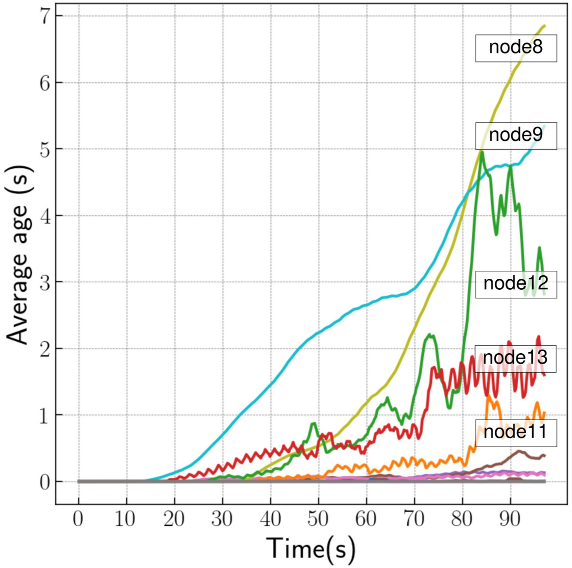




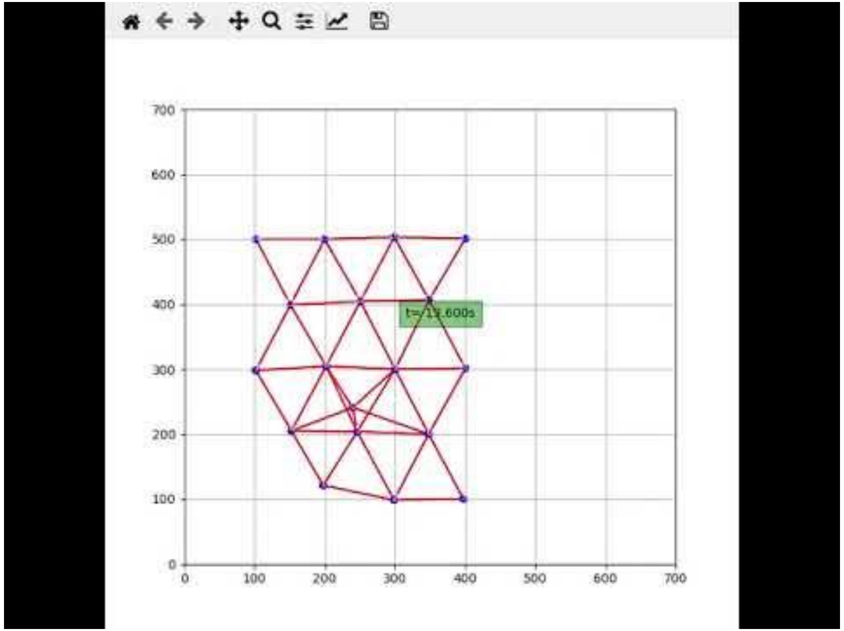
Congestion and Latency

Round Robin 30MB/s





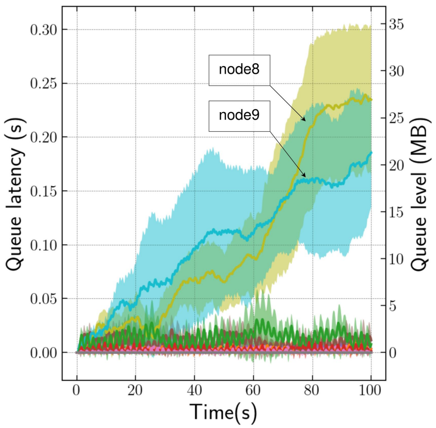
Can we Support Congested Areas?



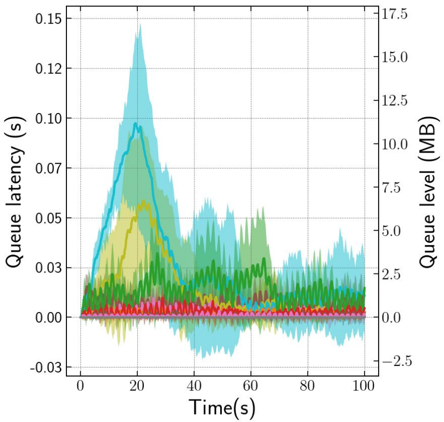
Congestion and Latency

Round Robin 30MB/s

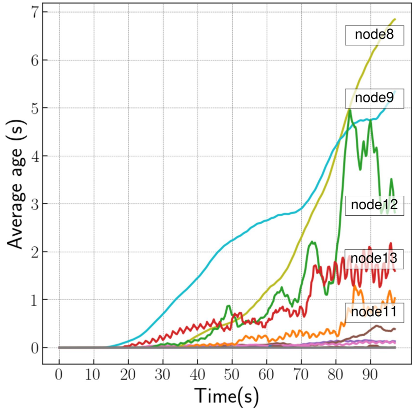
Without Support



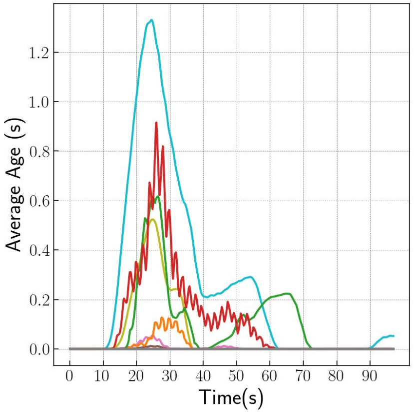
With Support



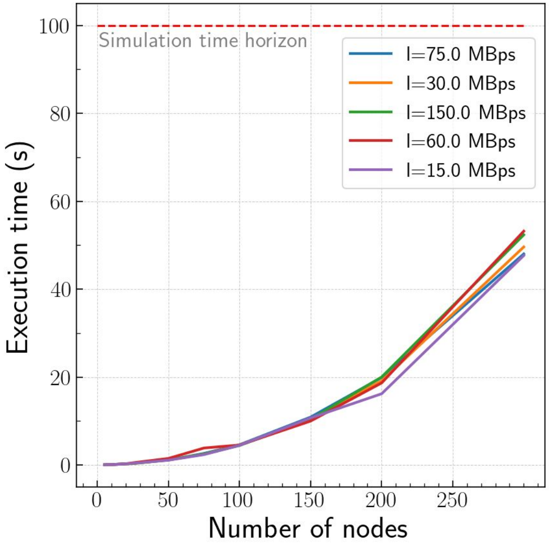
Without Support



With Support

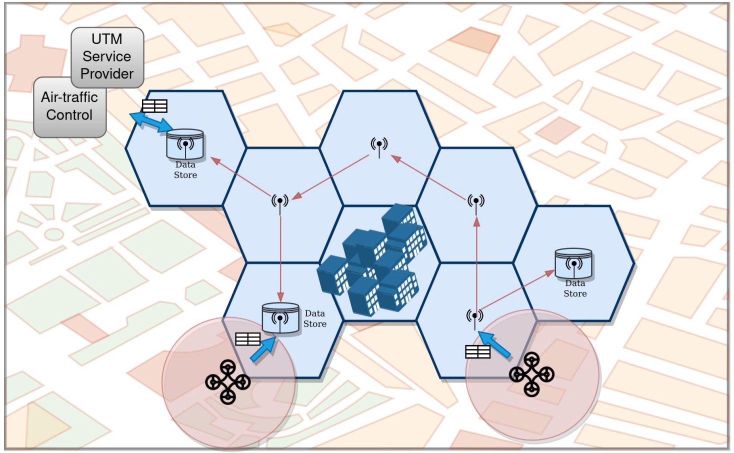


Scalability Assessment



Towards a Middleware

- Establish heuristics and control strategies to use the mobility in our favor, to reduce congestion and latency and increase system performance.
- Assess how to use those strategies to find better placement for replicas according to mobile node density across the topology.
  - Use these placement strategies to support other ongoing research about the use of distributed stores to support UAV position tracking for UTM



Conclusion

- We can model network traffic flow in Mobile Ad-hoc Computing with a lightweight model and measure the most common metrics in distributed applications such as throughput and latency.
- We can observe the influence of different topologies in application performance and choose the one that yields higher throughput and lower latency.
- We can also influence the and potentially lower the formation of congestion in the topologies by using the mobility of the nodes during runtime.

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