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Clipping for More Efficient Large-Scale Simulations in ns-3

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WNS3 2021 – Lightning Talk – June 24, 2021

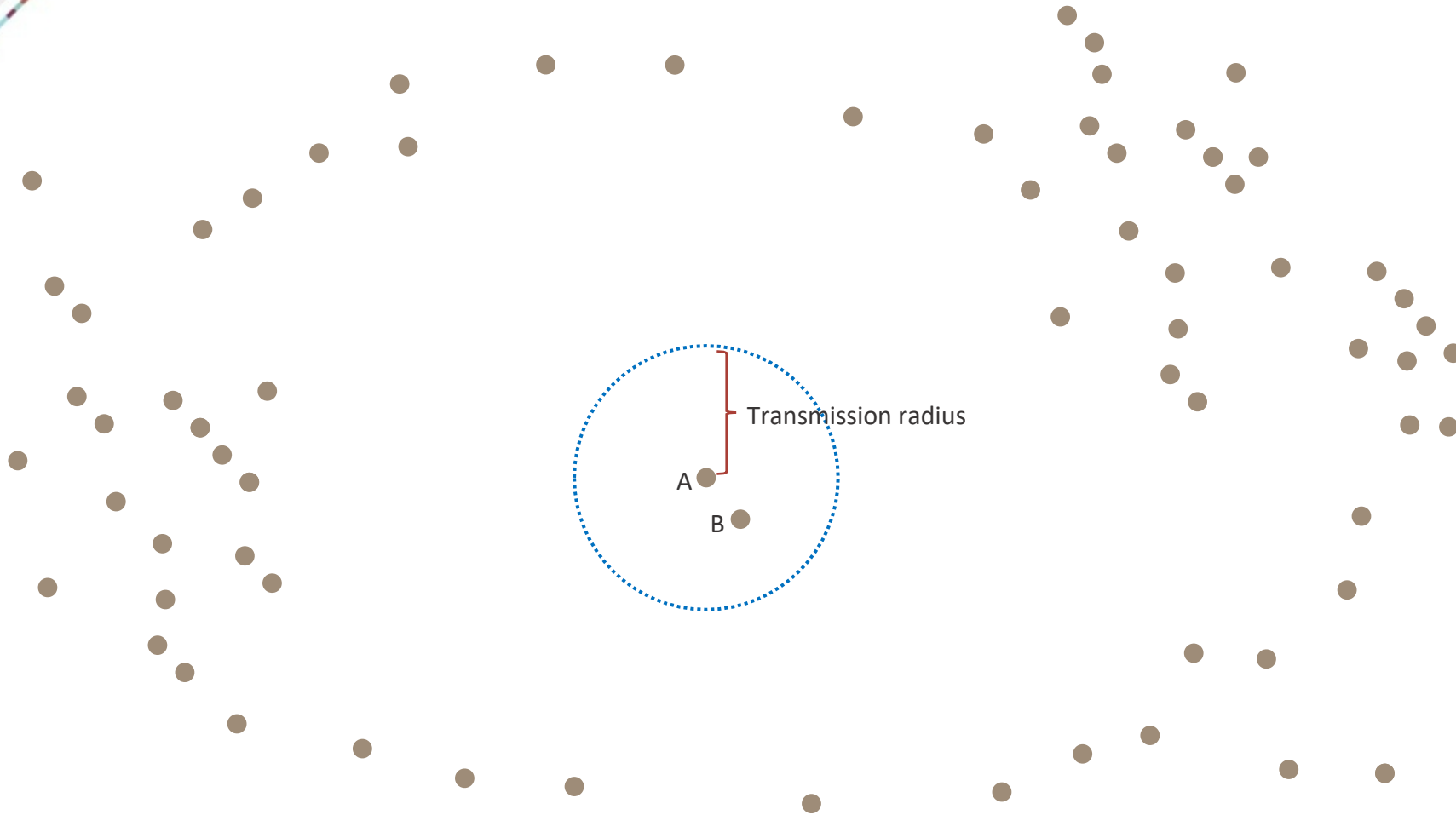
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Events Scheduled on Every Node



⋮ Receive event for every node

Event Priority Queue

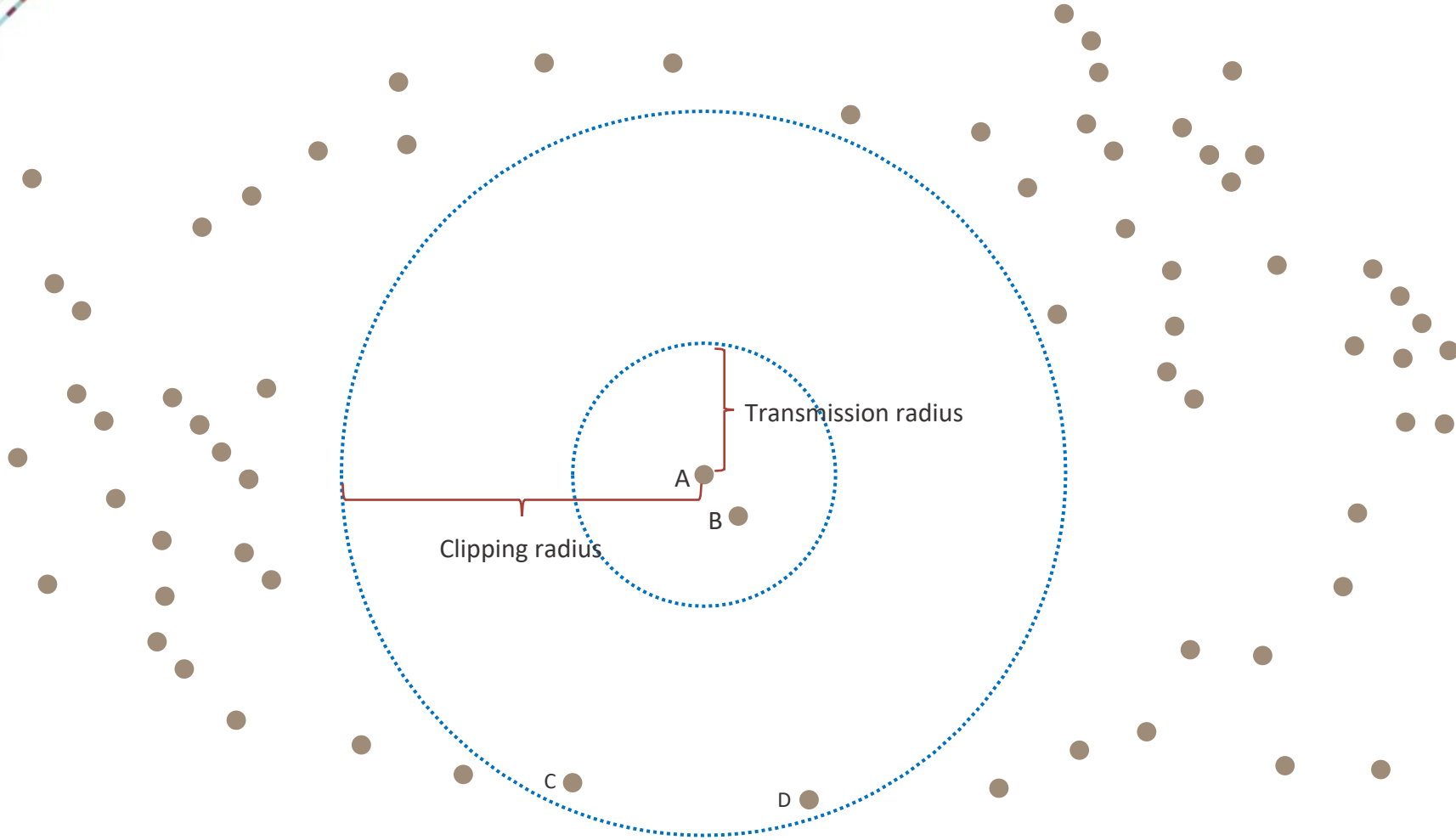
| | |
|-----------|---------|
| Receive N | 10.008 |
| Receive M | 10.0078 |
| Receive L | 10.0075 |
| Receive K | 10.007 |
| Receive J | 10.0068 |
| Receive I | 10.0067 |
| Receive H | 10.0066 |
| Receive G | 10.0065 |
| Receive F | 10.0064 |
| Receive E | 10.0062 |
| Receive D | 10.006 |
| Receive C | 10.005 |
| Receive B | 10.001 |



ns-3 sends every packet to every wireless receiver in the same channel in a simulation
This can be inefficient for certain large-scale simulations



Clipping Avoids Extra Overhead



Receive events
only for nodes
within clipping
radius

Event Priority Queue

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|-----------|--------|
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| | |
| Receive D | 10.006 |
| Receive C | 10.005 |
| Receive B | 10.001 |



Clipping: Only schedule receive events on nodes within some clipping radius

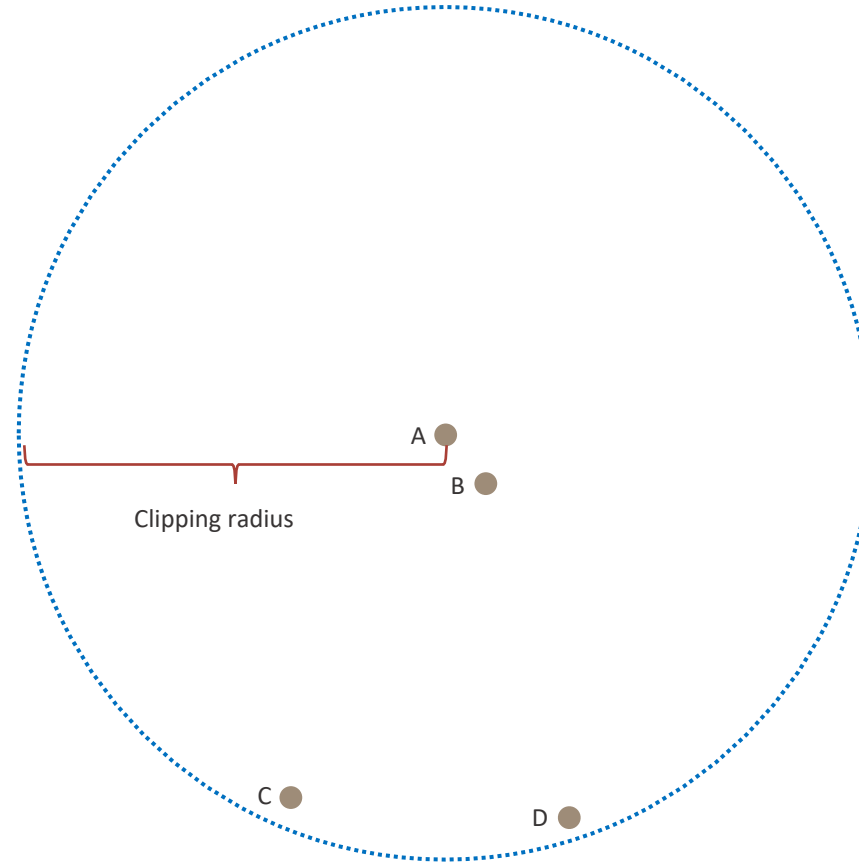


Determining Nodes Within the Clipping Radius

Need to be able to list all the nodes within A's clipping radius. {B,C,D}

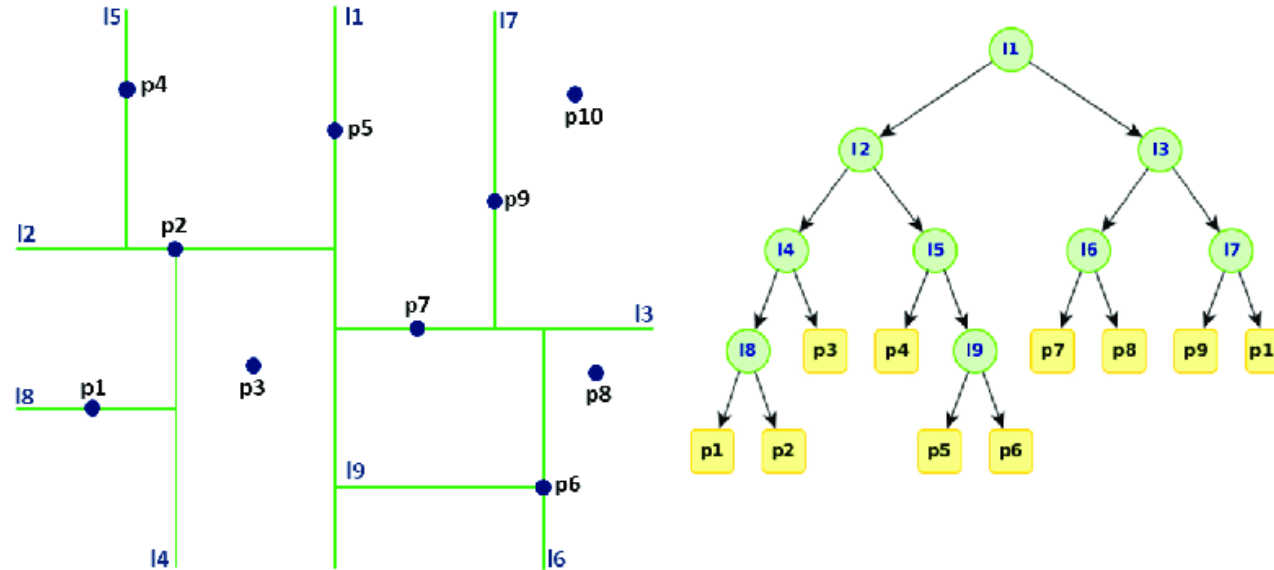


Bad idea: compute distance from A to every other node.





Spatial Indexing



[John Anzola, et. al.]

Instead, use a k-d tree space partitioning data structure to organize node locations for fast "look up" of nodes within range.



Clipping Feature is Being Merged into ns-3

GAND2017-7699C

A Novel Approach to Exponential Speedup of Simulation Events in Wireless Networks

| | | |
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Abstract.—We demonstrate a new approach that yields exponential speedup of communication events in discrete event simulations (DES) of mobile wireless networks. With the trending explosive growth of wireless devices including Internet-of-Things devices, it is important to have the capability to simulate wireless networks at large scale accurately. Unfortunately, current simulation techniques are inadequate for large-scale network simulation especially at high rate of total transmission events due to poor performance scaling. This has limited many studies to much smaller sizes than desired. We propose a method for attaining high fidelity DES of mobile wireless networks that leverage (i) path loss of transmissions and (ii) the relatively slower topology changes in a high transmission rate environment. Our approach guarantees a runtime of $k(r)O(\epsilon N)$ per event, where N is the number of simulated wireless nodes, r is a factor of maximum transmission range, and $k(r)$ is typically constant obeying $k(r) \ll N$.

I. INTRODUCTION

Wireless networks are ubiquitous. The de facto, cost-effective method for studying wireless networks is the use of discrete event simulation (DES). A DES of wireless networks has two fundamental event classes: (i) mobility and (ii) communication. On simulated wireless nodes, mobility events change their motion velocity while communication events affect their data transmissions and reception. The simulation of these events poses challenges that are generally not applicable to wired network simulations. The shared medium access for wireless networks and topology changes, imply that their simulators need to account for much more complicated channel models and inherent communication interference as well as node mobility. Despite these complications, DES remains the cost-effective approach for investigating the performance of protocols and applications in wireless networks.

The current standard approach for simulating wireless networks takes prohibitively long to simulate practical networks consisting of hundreds of wireless nodes and beyond on a day scale [1]–[5]. In standard simulation of wireless networks of N nodes, simulating a mobility event just involves updating the motion parameter of a node (e.g., velocity), which can be executed in time $O(1)$. Many simulators schedule data reception events at each node in the channel of the transmitter irrespective of distance from transmitter. This is due to the inherent broadcast nature of wireless mediums. Even

when one ignores nodes beyond a certain range, simulating a communication event still has a complexity of $O(N)$ because it involves querying every node for potential reception. The $O(N)$ cost per communication event limits current wireless simulators to hundreds of nodes over a day scale. Even if many computing cores are used to attain some speedup and size through parallel DES (PDES), the scaling of such simulations is often meager [2], [6]. The poor parallel scaling is due to the high inter-process communication required in simulating communication events with single distribution of multihop for wireless network simulation. For example, in [2] and [6], PDES scaling over serial DES was shown to be about 2X on an 8-processor run and 6X and 2X speedup on a 16-processor run of a wireless network simulation. It is our belief that relatively poor performance scaling is the reason behind very limited publications on performance of PDES for parallel wireless network simulations as noted by Nekovee and Sakuma in [5].

Our work describes a novel approach to speed up DES of large-scale wireless networks. We describe how our work can be deployed in a PDES environment but focus our studies on (serial) DES. The ns-3 network simulator used in one of our simulations currently does not provide a PDES implementation for wireless networks; ns-3 PDES is limited to wired networks. This means that our approach's performance in a PDES environment could not be given a complete treatment as of this writing. Our simulations demonstrate the performance improvements for a single processor run (DES) over the current approach and should extend to a PDES.

The need to have significantly faster DES simulators for large-scale wireless networks stems from problems of interest in academic, industry, and military sectors. In [1], the authors highlight some of the requirements for a high fidelity large-scale network simulator and propose a framework for attaining this called SWAN - Simulation of Wireless Ad hoc Networks. The main idea of the work was the ability to approximate spatio-temporal wireless channel effects with simplified stochastic equations and thereby enable better parallelism of simulators from reduced inter-process communication for channel effects simulation. However, its main drawbacks are that SWAN has long been unimplemented and its incorporation

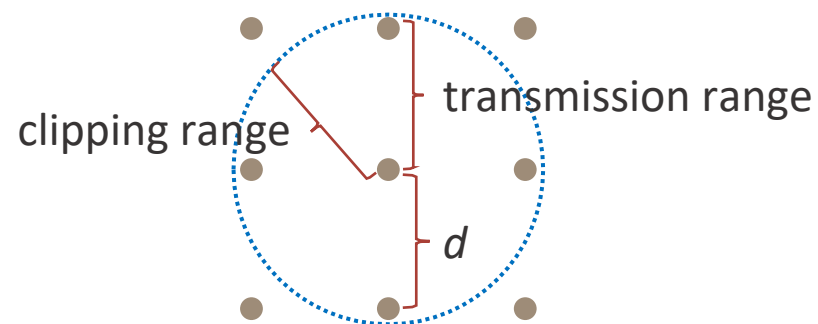
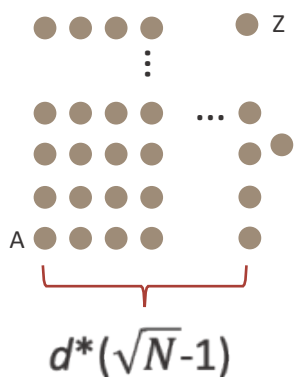


Published simulation improvements have now been integrated into the ns-3 simulator and are under review for inclusion



AODV Example

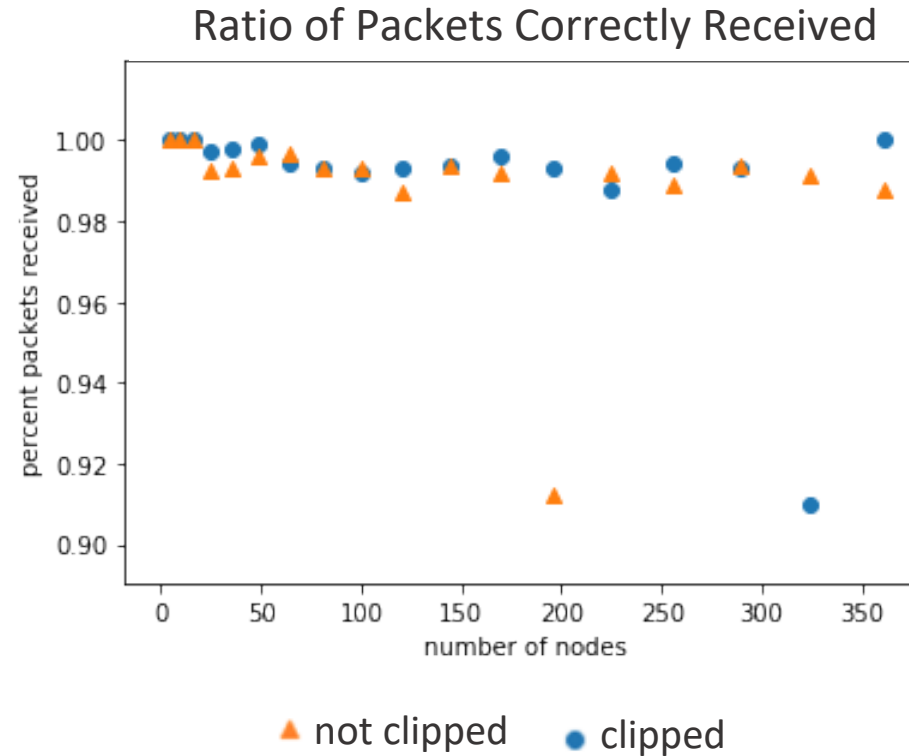
Grid of N nodes spaced d units apart



Use AODV Adhoc Routing protocol to route 1 packet/second from node A to node Z.



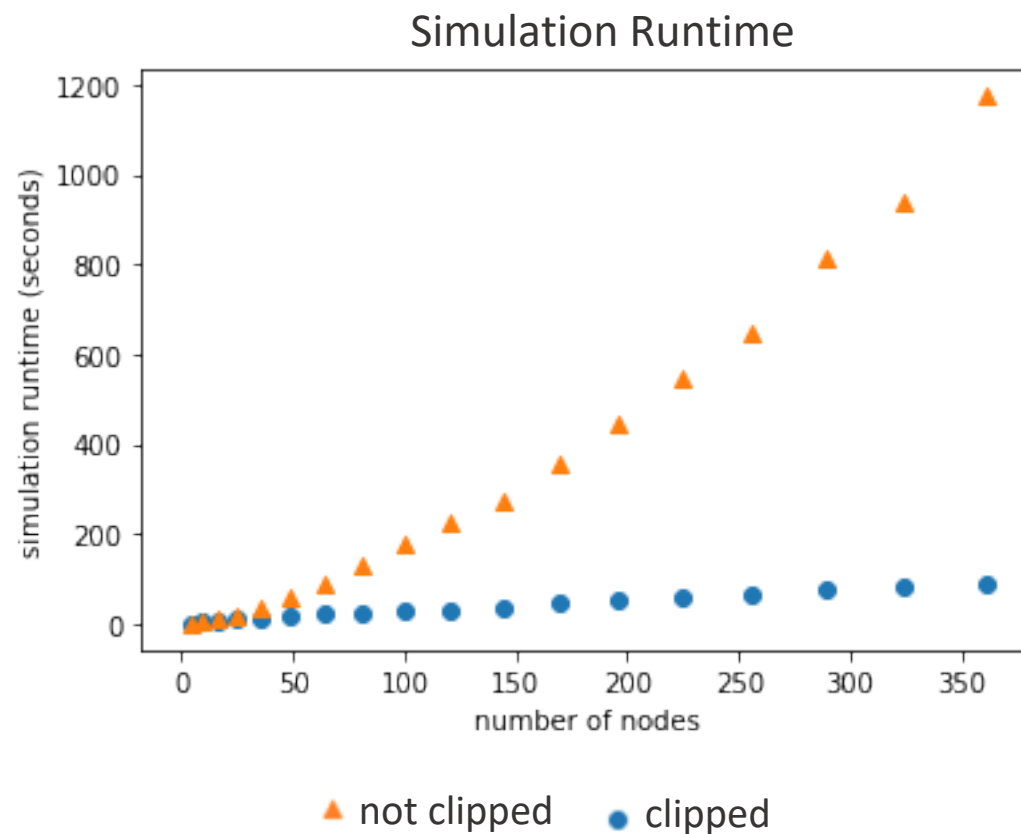
AODV Results: Similar packets received



Comparison of number of packets received with and without “clipping”
AODV drops a few packets (in both cases) while initially establishing routes.



AODV Results: Faster runtime



~14x speedup for 361 nodes



Questions?

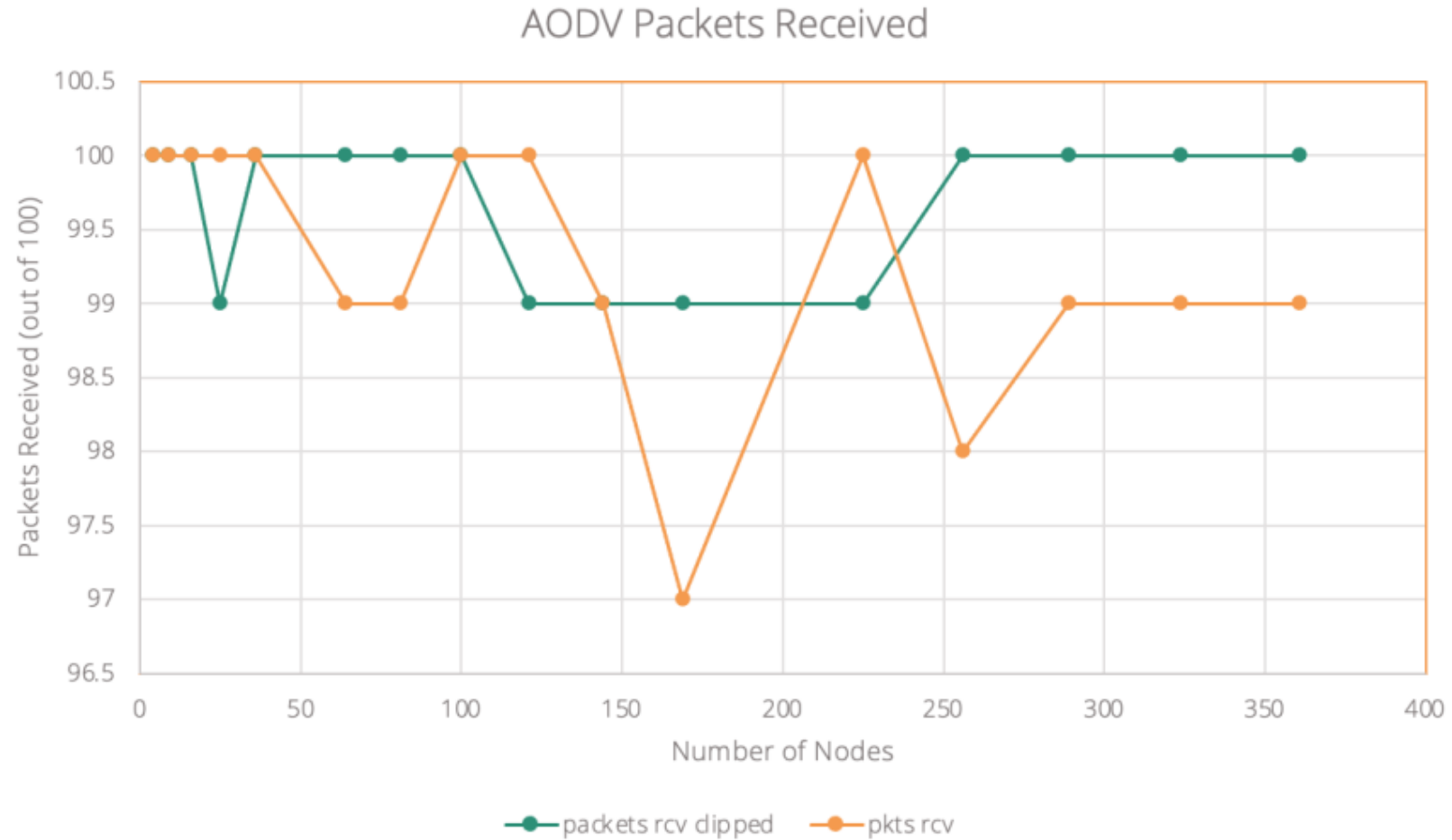
Happy to answer any questions now or
later via email: bdnewto@sandia.gov



Backup Content



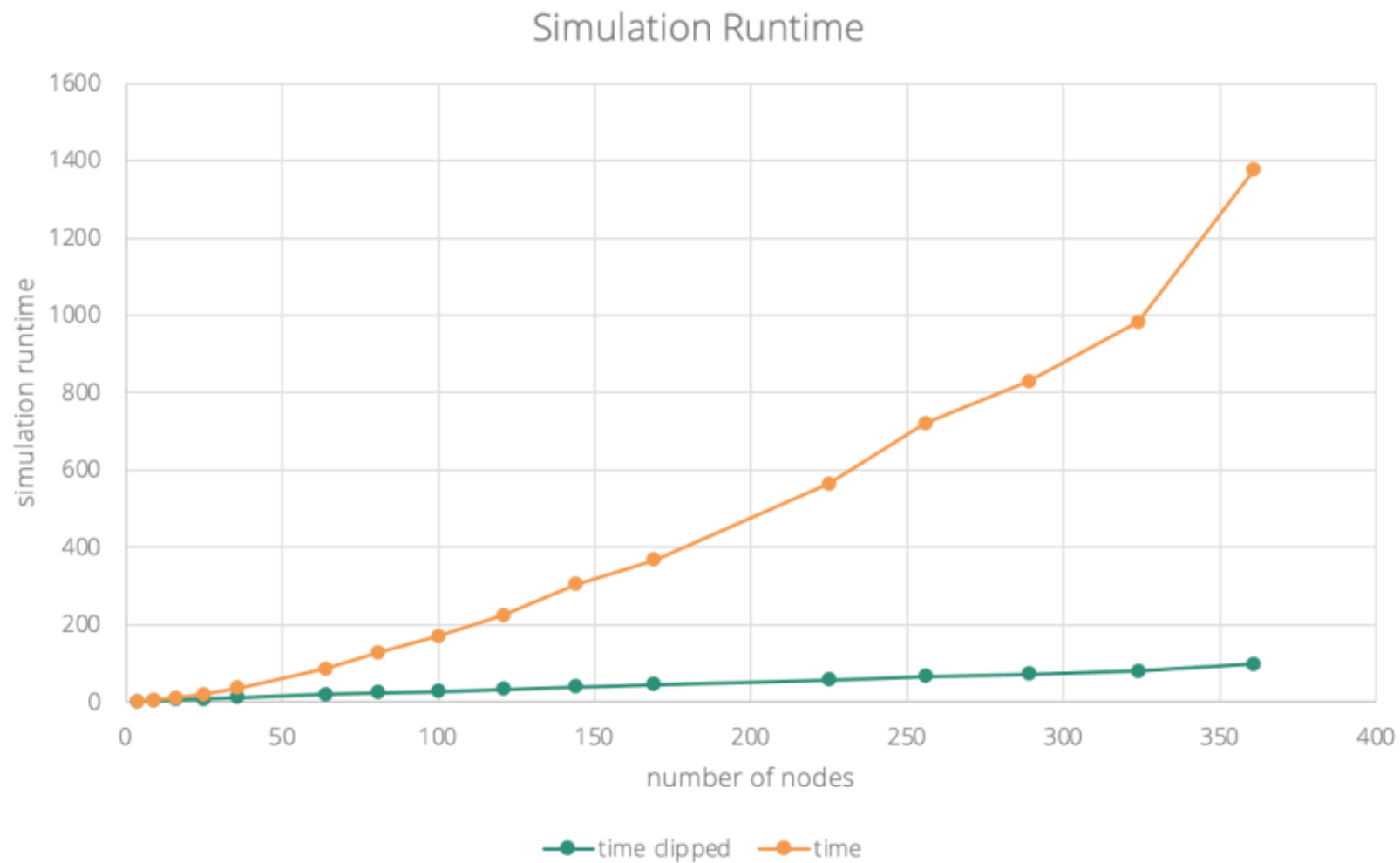
AODV Results: Similar packets received



AODV drops a few packets (in both cases) while initially establishing routes.



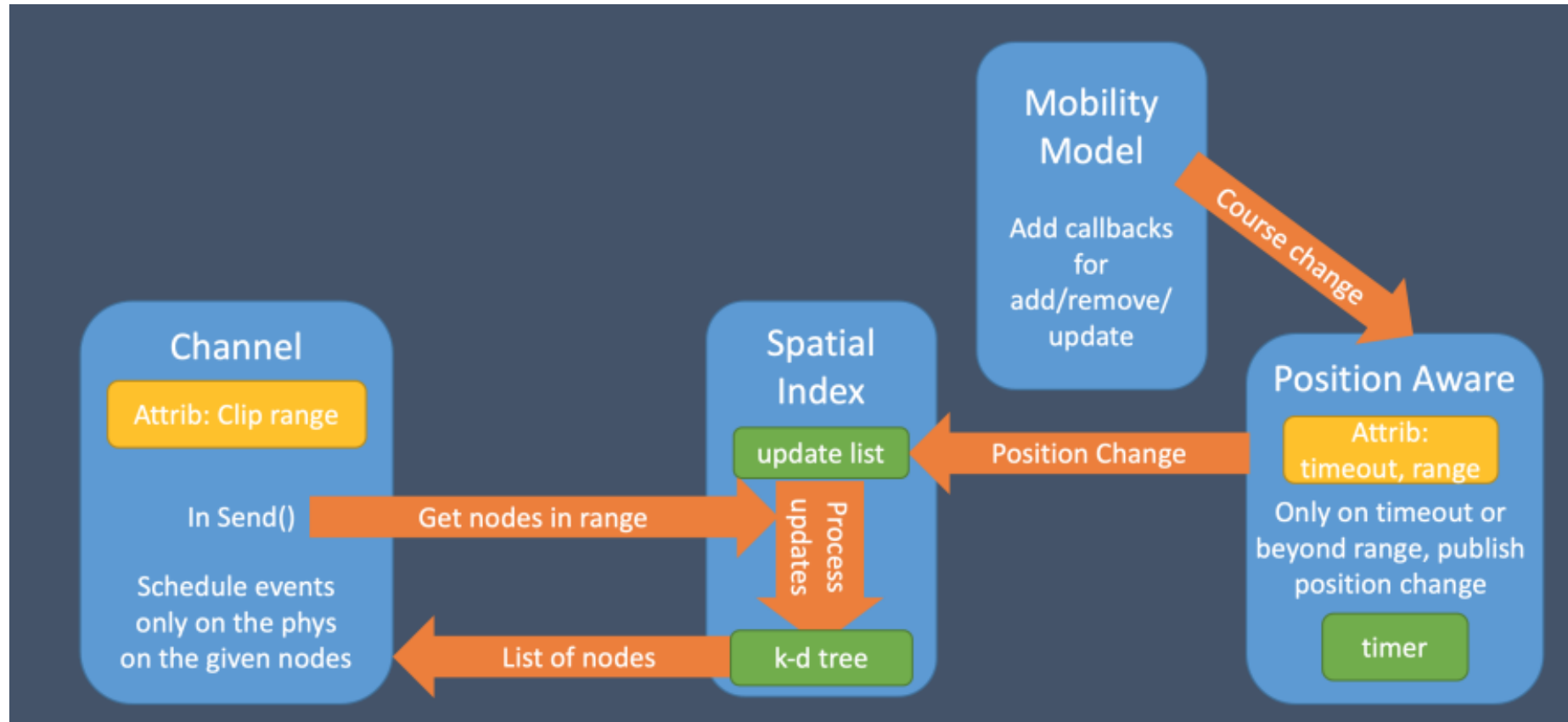
AODV Results: Faster runtime



14x speedup for 361 nodes



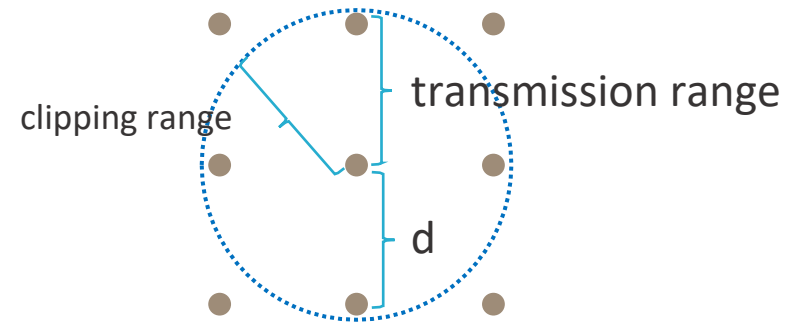
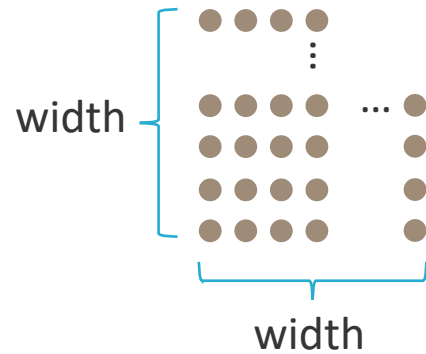
System Diagram



Position Aware “buffers” position updates. Spatial Index maintains a k-d tree of node positions. Channel now gets “nodes in range” before scheduling receive events.



Static Grid Simulation



Node separation distance (d) is set to be just under maximum transmission range. Data can only flow vertical and horizontal (not diagonal).

Clipping range is set such that receive events are scheduled only for nodes that can actually receive the transmission

Every node sends a packet to the broadcast IP address. Received by every node "in range". (in this case only vertical and horizontal neighbors).



Static Grid Results

Simulation Performance Comparison

using KMSim in NS-3.29

