A MATLAB Tool for the Study of Propagation Maps in MANETs

Scott L. Rosen
The MITRE Corporation

Part of MITRE Sponsored Research in Advanced Tactical Networking with John A. Stine of the MITRE Corporation

Goals

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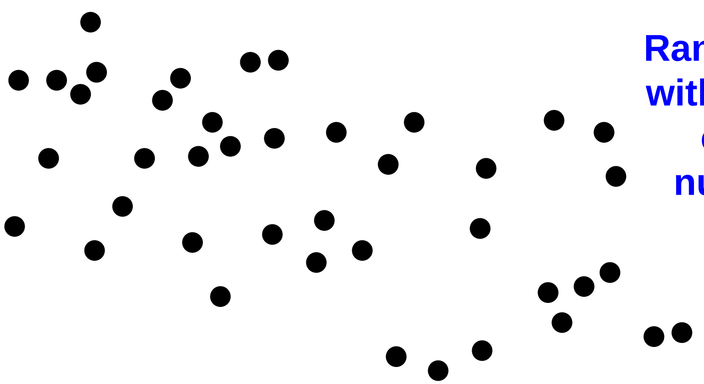
- **Build tactical networks using ad hoc networking**
  - **Network nodes consist of users that have radios**
  - **These radios automatically self form into a network**
  - **These networks adapt to mobility**

- **Our focus is on protocols that**
  - **Allow users operational flexibility**
  - **Exploit physical layer techniques to provide capacity**
  - **Enable users to control the use of their resources for operational benefits**
  - **Are easy for users to understand**

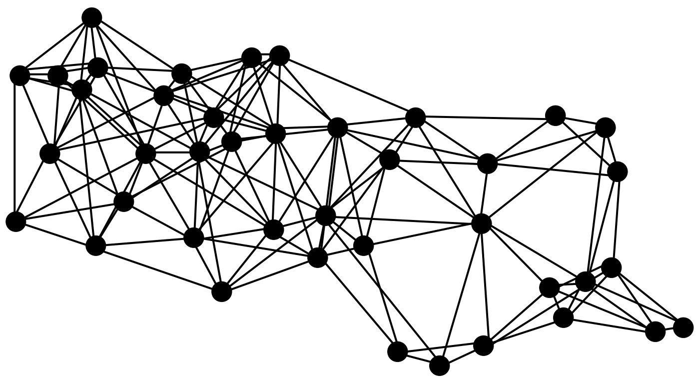
Build the *first* tactical mile

Current approaches

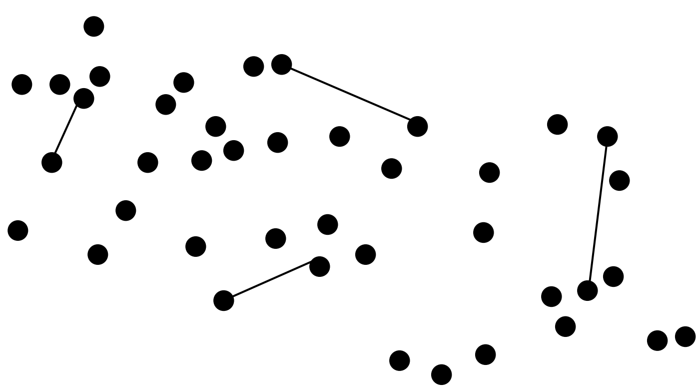
- **Favor the wireline view**
  - **Access mechanisms attempt to create links**
  - **Routing protocols try to track links to understand topology**



Random node placements with wireless connectivity can result in a large number of overlapping links



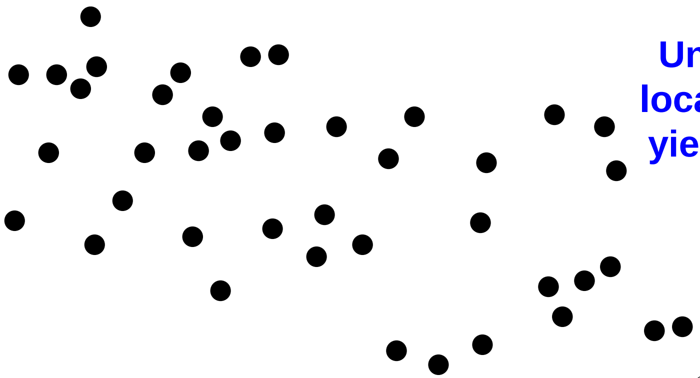
But in an instant only a small subset can be used



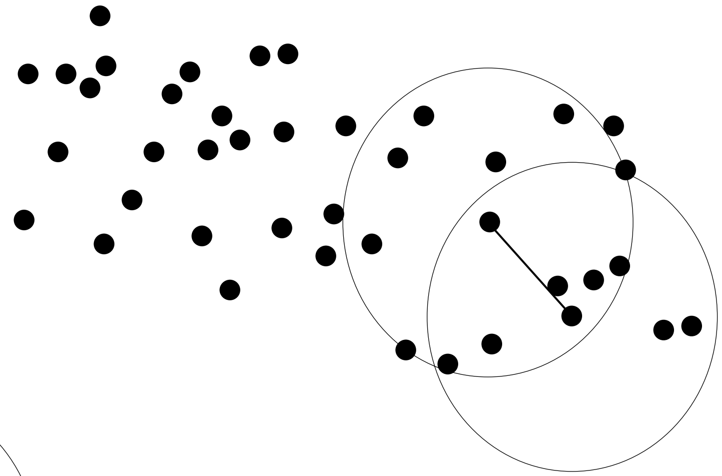
The link abstraction creates overhead and does not accurately represent the resource we want to manage

Our approach

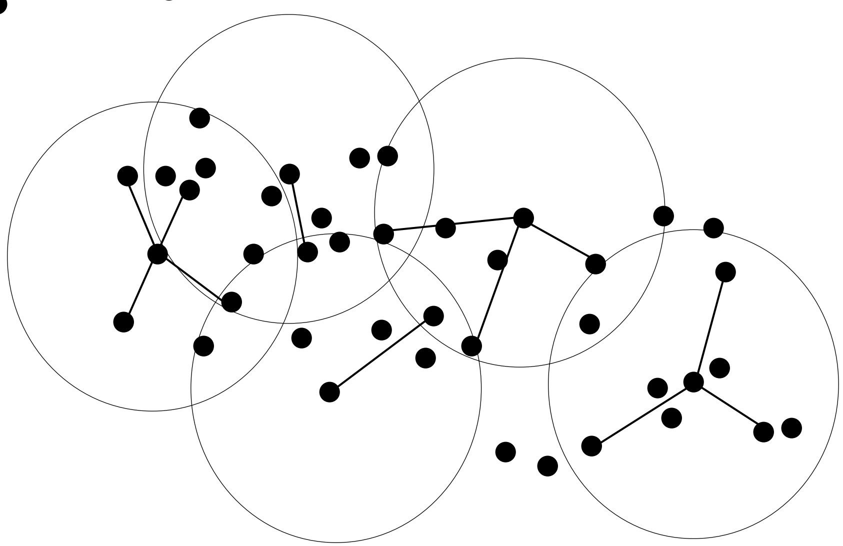
- **Favors the wireless view**
  - **Access mechanisms attempt to create the cellular geometry which enables exploitation of cellular technologies**
  - **Routing protocols track nodes to understand topology**



Understanding of node location and propagation yields an understanding of connectivity



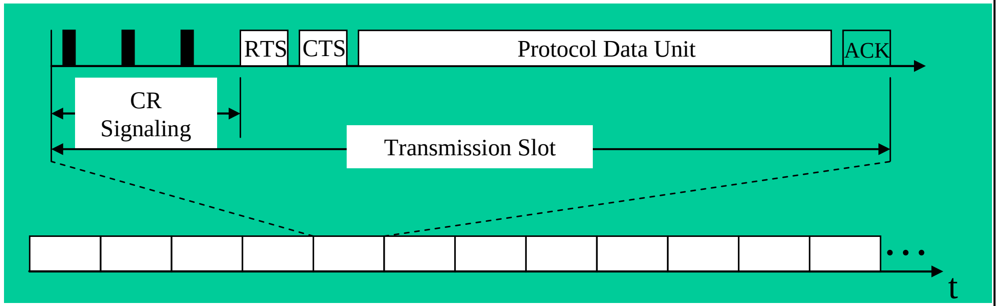
Results in a greater density of links that can be used simultaneously



The mechanisms to create the network geometry and to track nodes are comparatively efficient and enable many benefits

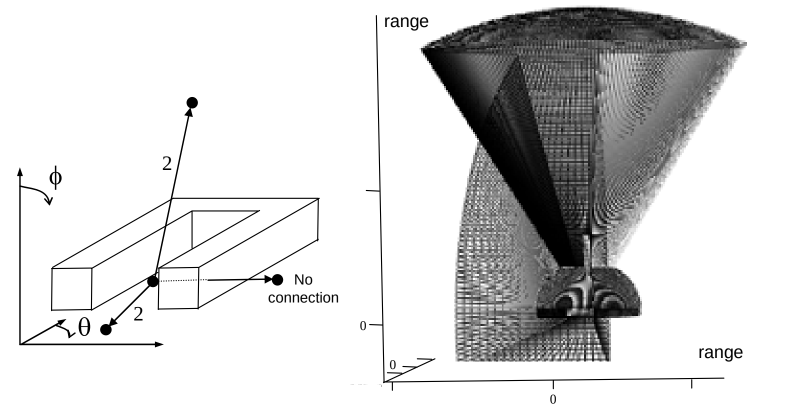
Enabled by two protocol approaches

- **Synchronous collision resolution (SCR) MAC protocol**



- Characteristics
  - Time-slotted channel
  - Nodes with packets to send contend in every slot
  - Signaling is used to arbitrate contentions
  - Packet transmissions occur simultaneously
- Features include QoS, energy conservation, and exploitation of specialized physical layers

- **Node state routing (NSR) protocol**



Propagation map → (2, 255, 30, 2.5, 120, 2, 140, 2.5, 255, 100, 7, 0)

- Characteristics
  - Uses node location and propagation maps to infer links
  - States may be any relevant information about nodes
- Provides a single information distribution mechanism for all networking functions

Propagation Maps

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PROBLEM: Solve for vectors of minimum length, which accurately predict connectivity to each node in the network

A constraint considered in this optimization problem is the goodness of fit between the path loss measurements and the propagation map's corresponding path loss for the sample points

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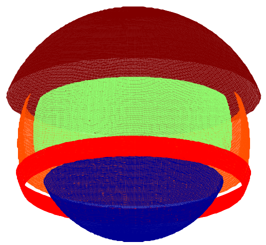
Example Map and notation



$n \quad \theta \quad \phi \quad n \quad \theta \quad n \quad \theta \quad \phi \quad n \quad \theta \quad \phi \quad n$

[2 255 69 4.5 100 3.1 255 100 2.7 255 110 4.7 0]

Exact Formulation

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Min $3\sum f_j + 2\sum d_{ij} - 1$ **(length of propagation vector)**

Subject to:

$\left(Z_{ij} - Z_{i,j+1}\right)\left(1 - c_{ij}\right) = 0 \quad \forall i, j \neq 180$ **(to indicate exponent deviations between latitudinally adjacent elements in *Z*)**

$\left(\sum_i c_{ij}\right)\left(1 - f_j\right) = 0 \quad \forall i, j \neq 180, f_{180} = 1$ **(to count number of phi deviations in *Z*)**

$f_j\left(Z_{i,j} - Z_{i+1,j}\right)\left(1 - d_{ij}\right) = 0 \quad \forall i \neq 255, j$ **(to count number of theta deviations in *Z*)**

$Z_{ij}^{\min} \leq Z_{ij} \leq Z_{ij}^{\max} \quad \forall i, j$ **(each *n* value in *Z* must adhere to window constraints)**

$\frac{\sum_k \left(e_{ij}^+ + e_{ij}^-\right)}{n} \leq G$ **(average deviation in *n* from sample points must be less than *G*)**

$e_{ij}^+ - e_{ij}^- = Y_{ij} - Z_{ij} \quad \forall i, j \in k$ **(to remove absolute value)**

$e_{ij}^+, e_{ij}^- \geq 0 \quad \forall i, j \in k$ **(to remove absolute value)**

$f_j, c_{ij}, d_{ij} \geq 0 \quad \forall i, j$

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Algorithms Developed to Solve this Optimization Problem

Solving for the exact formulation may take too long in a real network scenario so more efficient algorithms are developed and tested

NLP: Minimize length of vector such that goodness of fit is also considered as well as connectivity.

IP: Minimize length of vector such that connectivity is properly predicted at all sample measurement points.

Two-phase cut (GA/LP): At each iteration cut a subset of the vector (containing no more than one *n*), solve for the remaining *n*, , values in the vector that minimize goodness of fit. Before each cut is made an LP is solved to smooth the *n* values in the vector and the subset containing the *n* with the smallest deviation to adjacent *n* is cut. Proceed with reducing vector until connectivity constraint cannot be achieved.

Fast map (GA): Start with a vector of form [*n*, 0]. Using GA, solve for the best vector at the current length. If connectivity constraint cannot be achieved then increase the length of the vector. Continue until acceptable goodness of fit can be achieved.

Constraint Based – Simply iterate through all possible n theta and phi values at each length, starting at length 3, until a combination is found that satisfies constraints on connectivity and goodness of fit.

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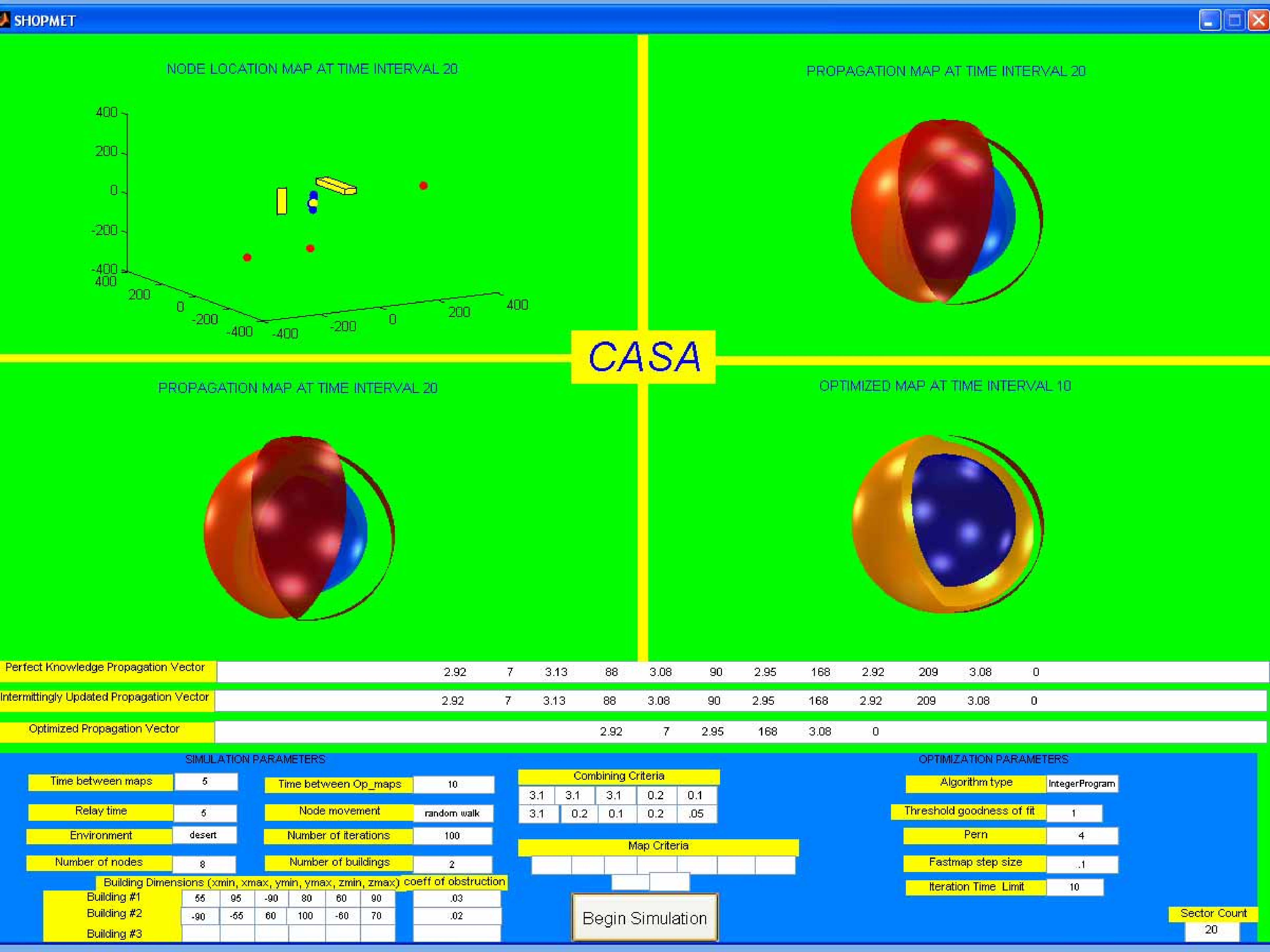
SHOPMET

- **Single Hop Propagation Map Evaluation Tool (SHOPMET) is used to study the effectiveness of the proposed algorithms.**

- **SHOPMET simulates the collection of path loss measurements and generation of propagation maps for a single node within a MANET scenario**

- **It is developed in MATLAB and interfaces with DLL libraries (used in OPNET) for network data management support.**


SHOPMET
NODE LOCATION MAP AT TIME INTERVAL 20
400
200
0
-200
-400
400
200
0
-200
-400
-400
-200
0
200
400
PROPAGATION MAP AT TIME INTERVAL 20
CASA
PROPAGATION MAP AT TIME INTERVAL 20
OPTIMIZED MAP AT TIME INTERVAL 10
Perfect Knowledge Propagation Vector
2.92 7 3.13 88 3.08 90 2.95 168 2.92 209 3.08 0
Intermittingly Updated Propagation Vector
2.92 7 3.13 88 3.08 90 2.95 168 2.92 209 3.08 0
Optimized Propagation Vector
2.92 7 2.95 168 3.08 0
SIMULATION PARAMETERS
Time between maps
5
Time between Op_maps
10
Relay time
5
Node movement
random walk
Environment
desert
Number of iterations
100
Number of nodes
8
Number of buildings
2
Building Dimensions (xmin, xmax, ymin, ymax, zmin, zmax) coeff of obstruction
Building #1
55 95 -90 80 60 90 .03
Building #2
-90 -55 60 100 -60 70 .02
Building #3
Combining Criteria
3.1 3.1 3.1 0.2 0.1
3.1 0.2 0.1 0.2 .05
Map Criteria
Begin Simulation
OPTIMIZATION PARAMETERS
Algorithm type
IntegerProgram
Threshold goodness of fit
1
Pern
4
Fastmap step size
.1
Iteration Time Limit
10
Sector Count
20