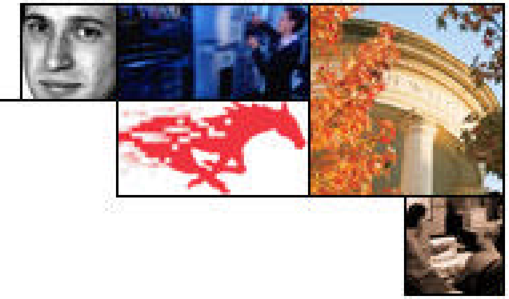

## 4th Workshop on Applications and Services in Wireless Networks

# A Multicast Protocol for Mobile Ad Hoc Networks Using Location Information

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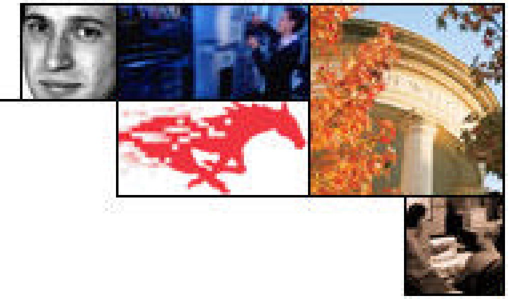
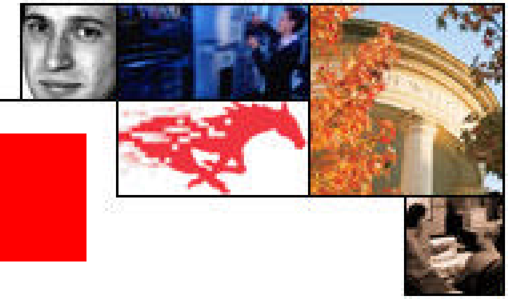
Boston University, Boston, Massachusetts, USA
August 8-11, 2004



# Outline

- Introduction and Motivations
- Background
- Multicast Protocol Design
- Illustrative Example
- Summary and Perspectives



# Introduction and Motivations

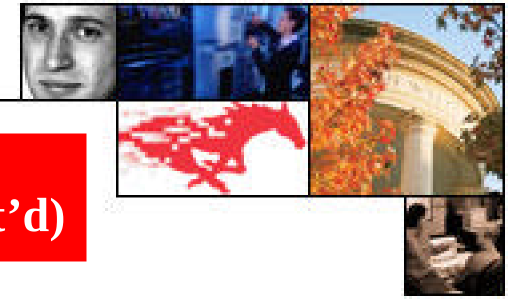
**Definition:** **A *mobile ad hoc network* (MANET) is a collection of mobile nodes without any infrastructure**

## Mobile node behavior

- **Mobile nodes act as *hosts* (running applications) and *routers* (forwarding for others)**

## MANET architectural properties

- **Autonomous nodes**
- **Multihop routing**
- **Limited capabilities**
- **Distributed operation**
- **Dynamic topology**



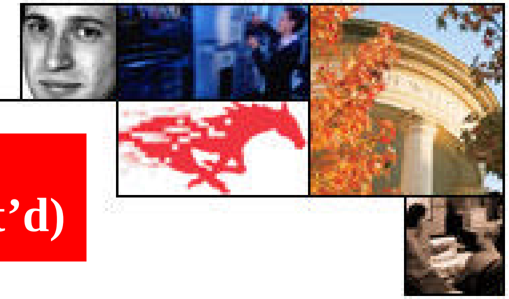
# Introduction and Motivations (cont'd)

## MANET routing protocols

- Proactive vs. reactive
- Unicast vs. multicast
- One-to-one: unicasting
- One-to-many: multicasting

## Ad hoc networking applications

- Establishing infrastructured networks is impossible or not cost effective
- Temporary networks for urgent situations such as battlefields, earthquake, conferencing, etc.



# Introduction and Motivations (cont'd)

## Why multicast routing protocols?

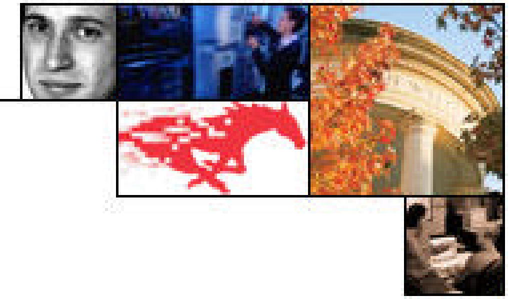
- Same message sent to a group of mobile nodes
- Group communication in military applications

## Our objective

- Develop a multicast protocol for MANETs
- Minimize routing overhead

## Tools

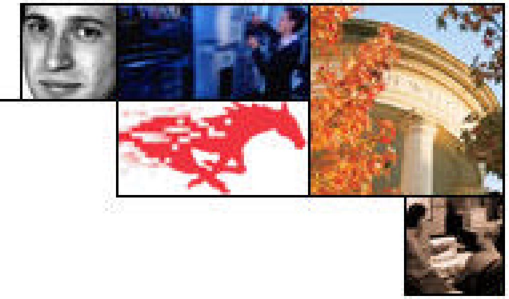
- Location information (GPS-enabled mobile nodes)
- Voronoi diagrams structural properties



# Background

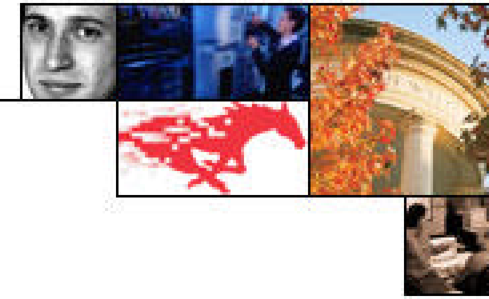
## Voronoi diagram

- **Geometrical construct defined by a discrete set of sites (points) $S = \{ s_1, s_2, s_3, \ldots, s_n \}$ in the plane**
- ***Nearest-neighbor rule:* each point is assigned with the closest region of the plane to it**
- $B(s_i, s_j) = \{ p \text{ Î Â}^2 \mid d(s_i, p) = d(s_j, p) : s_i, s_j \text{ Î } S \}$: **bisector of $s_i$ and $s_j$ in $S$, where $d$: *Euclidean* distance function**



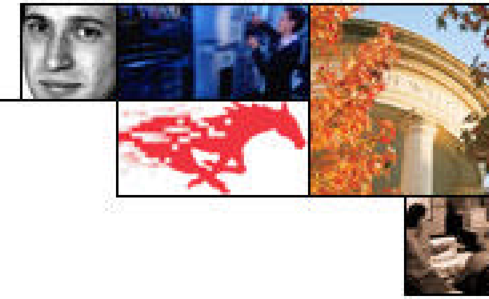
# Background (cont'd)

- $HP(s_i,s_j) = \{p$ Î Â $^2 \mid d(s_i,p) < d(s_j,p) : s_i,s_j$ Î $S\}$
- $HP(s_j,s_i) = \{p$ Î Â $^2 \mid d(s_j,p) < d(s_i,p) : s_i,s_j$ Î $S\}$
- $VR(s_i,S) =$ Ç $HP(s_i,s_j)$: *Voronoi region* of $s_i$
- **Boundary of a Voronoi region:** ***Voronoi edges***
- **Endpoints of a Voronoi edge:** ***Voronoi vertices***



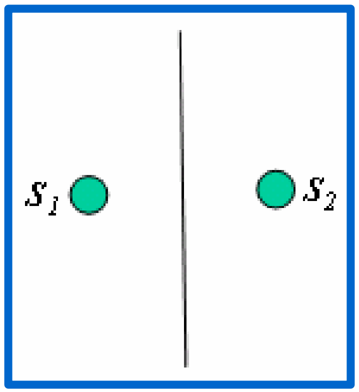
# Background (cont'd)

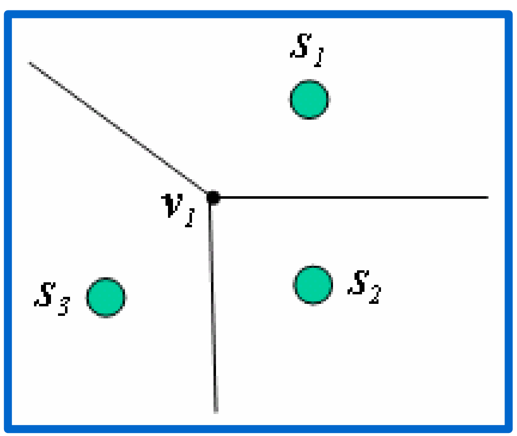
- The boundary of a region has at most *n-1* Voronoi edges
- Voronoi regions constitute a polygonal partition of the plane: *Voronoi diagram V(S)*
- $V(S) = \bigcup VR(s_i, S)$: *Voronoi diagram* of *S*

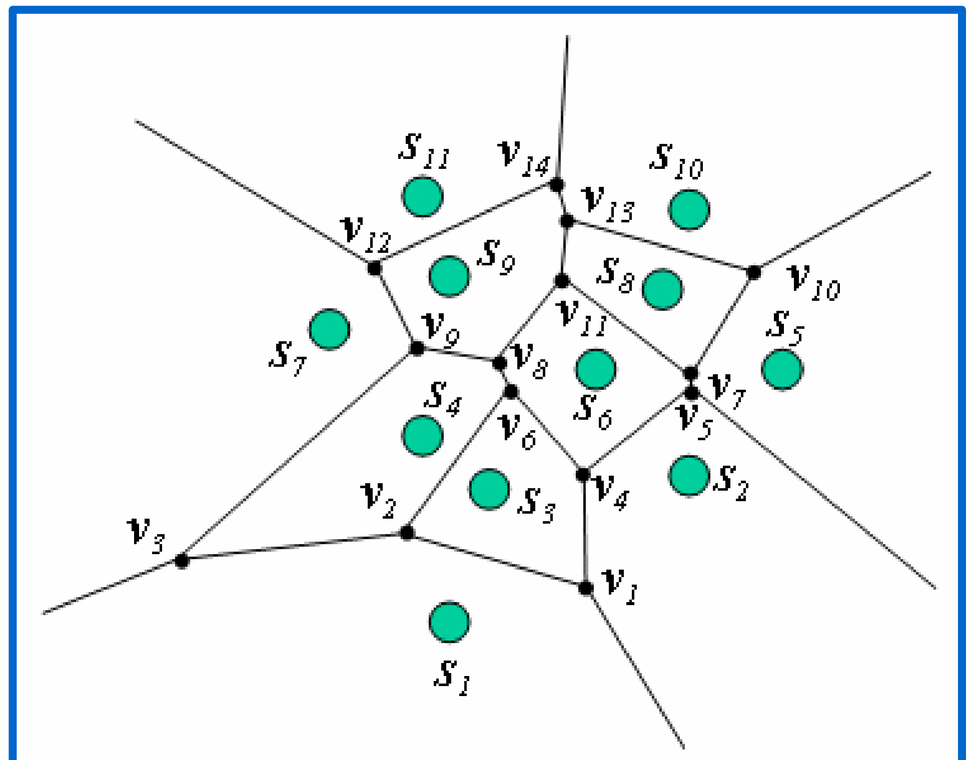


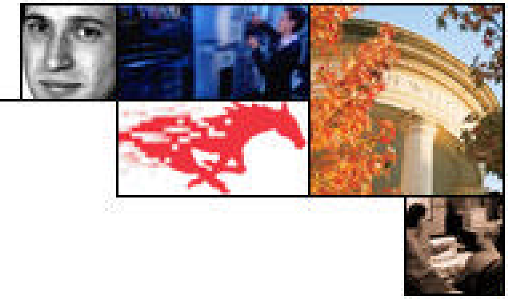
# Background (cont'd)

## Illustrative Examples





# Background (cont'd)

## Voronoi Diagram Construction Algorithms

- Straightforward approach – construct one region at a time as the intersection of *n-1* half-planes Þ $O(n^2)$ time for one region Þ $O(n^3)$ time algorithm
- Divide-and-conquer algorithm Þ $O(n \log n)$
- Shamos and Hoey Þ $O(n \log n)$ time algorithm

# Multicast Protocol Design

## MANET modeling

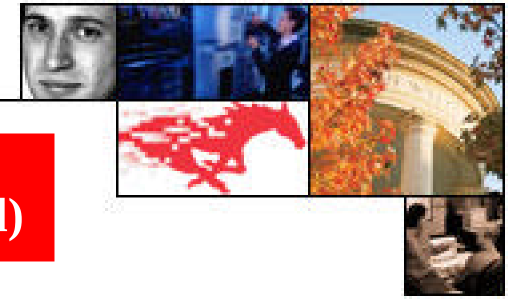
- MANETs can be modeled using Voronoi diagram

## Neighboring node set

- $NN(s_i)$: neighboring node set of $s_i$ is the set of MANET nodes within the transmission range of $s_i$

## Assumptions

- GPS: location information to MANET nodes



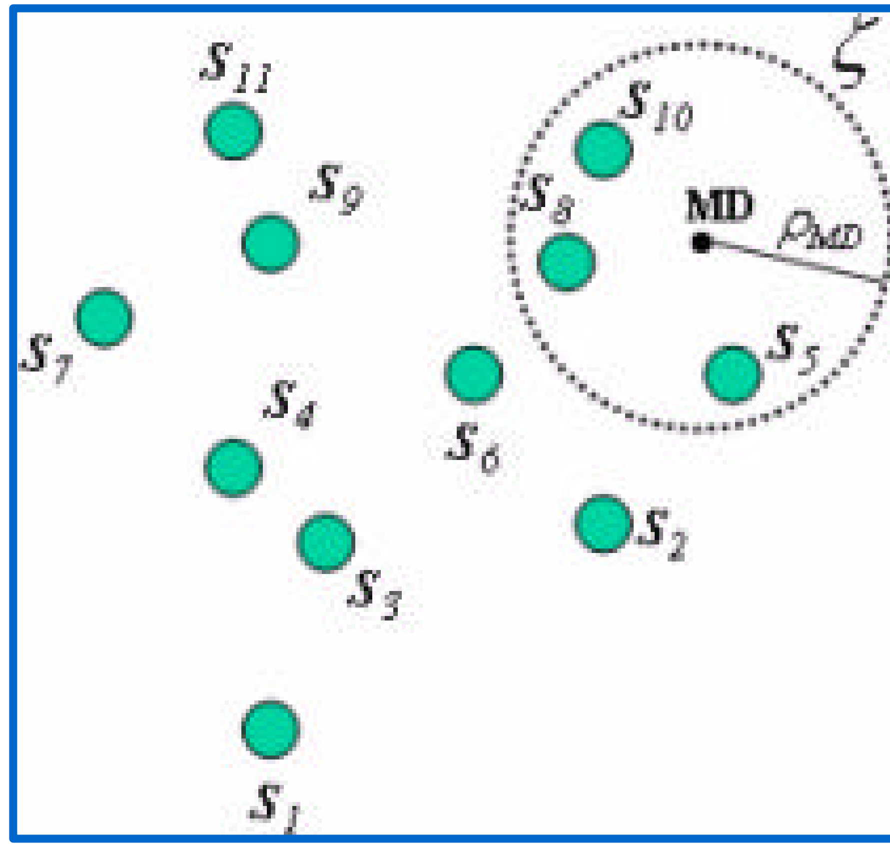
# Multicast Protocol Design (cont’d)

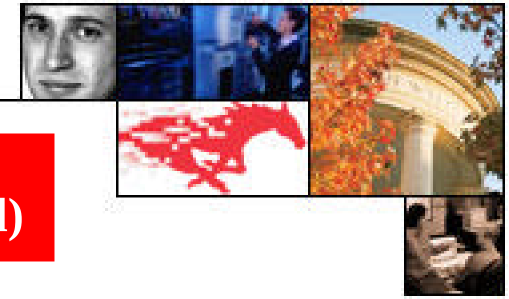
- **MANET node $s_i$ broadcasts its location information when joining MANET**
- **When changing its location, a MANET node might have to broadcast its location information**
  - **Þ decision based on its new location and current distances to its neighboring nodes**
- **Neighboring nodes reply back with their location information with *time-to-live = 1***

# Multicast Protocol Design (cont'd)

## Multicast domain

- Planar region
- $z = (MD, r_{MD})$, where $MD = (x_{MD}, y_{MD})$
- Membership to the multicast group
  $d(s_i, MD)$ £ $r_{MD}$
- $\{s_5, s_8, s_{10}\}$: multicast group wrt to $s_1$

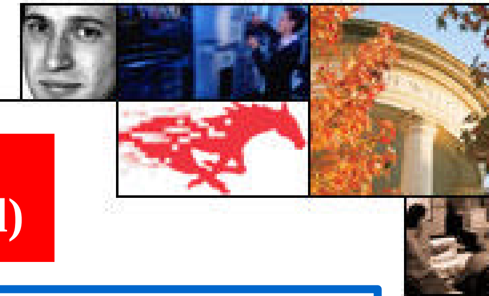




# Multicast Protocol Design (cont'd)

## Authorized Forwarders

- **MANET node $s_a \in NN(s_s)$ is an *authorized forwarder* of a multicast packet broadcast by $s_s$ if $s_a$'s Voronoi region share at least one Voronoi edge with that of MD in $s_s$'s localized Voronoi diagram $VG_{ss}$ wrt to $NN(s_s) \cup \{s_s\} \cup \{MD\}$**
- **$s_a$ constructs its localized Voronoi diagram wrt to $NN(s_a) \cup \{s_a\} \cup \{MD\} \setminus (AF(s_{cs}) \cup \{s_{cs}\})$**



# Multicast Protocol Design (cont'd)

## Algorithm

**Algorithm: Multicast distribution Protocol**

**Begin**

// when a source node $s_s$ sends a packet $MP$ to a
// multicast group $MG$ whose multicast
// domain is $\zeta = (MD, \rho_{MD})$

1. Compute the Voronoi graph $VG_{s_s}$
2. Find a subset of authorized forwarders $AF$
3. Append $s_s$'s address and location, and $AF$, and current time $\tau$ to $MP$
4. Broadcast $MP$ to $NN(s_s)$

// When an intermediate node $s_i$ gets $MP$

5. if $s_i$ is a member of $MG$ then
   get $MP$ and broadcast it to $NN(s_i)$
6. else if $s_i$ is a member of $AF$ then
7. Compute the Voronoi graph $VG_{s_i}$
8. Identify a new subset of authorized forwarders $AF'$
9. Append $s_i$'s address and location, and overwrite $AF$ with $AF'$
10. Broadcast the new $MP$ to $NN(s_i)$
11. else if $s_i \in \zeta$ at time $\tau$ then
12. consume $MP$
13. else drop $MP$
14. endif
15. endif
16. endif

**end**

# Illustrative Example

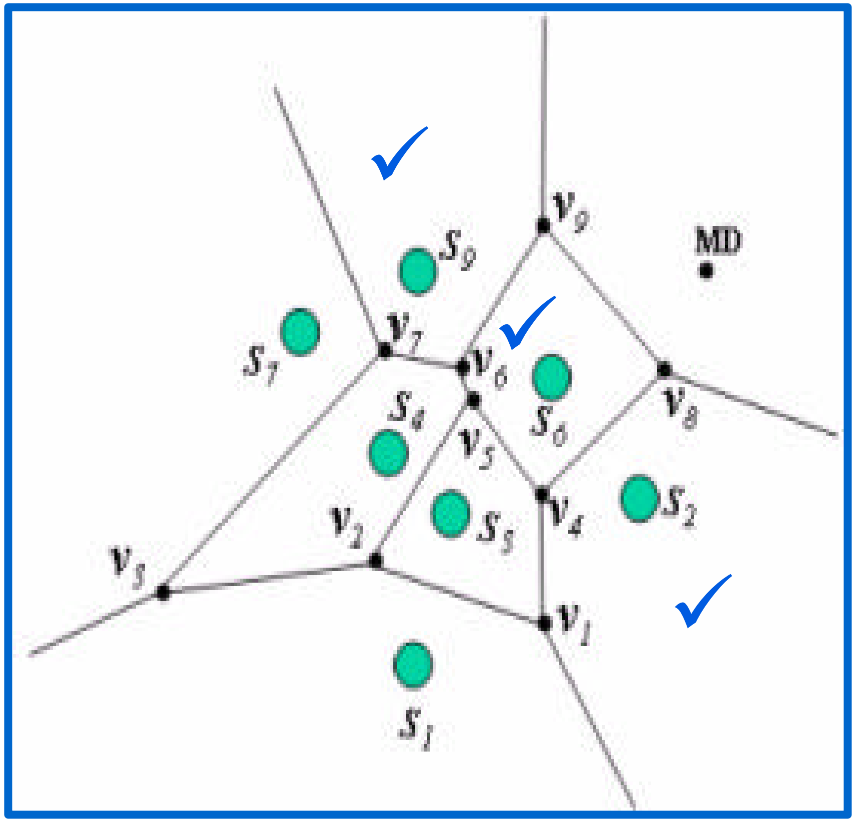
- **Assume $s_1$ wants to send a multicast packet to**

  **z = (MD, $r_{MD}$)**
- ***NN($s_1$) = {$s_2$,$s_3$,$s_4$,$s_6$,$s_7$,$s_9$}***

  ***NN($s_2$) = {$s_1$,$s_3$,$s_5$,$s_6$,$s_8$}***

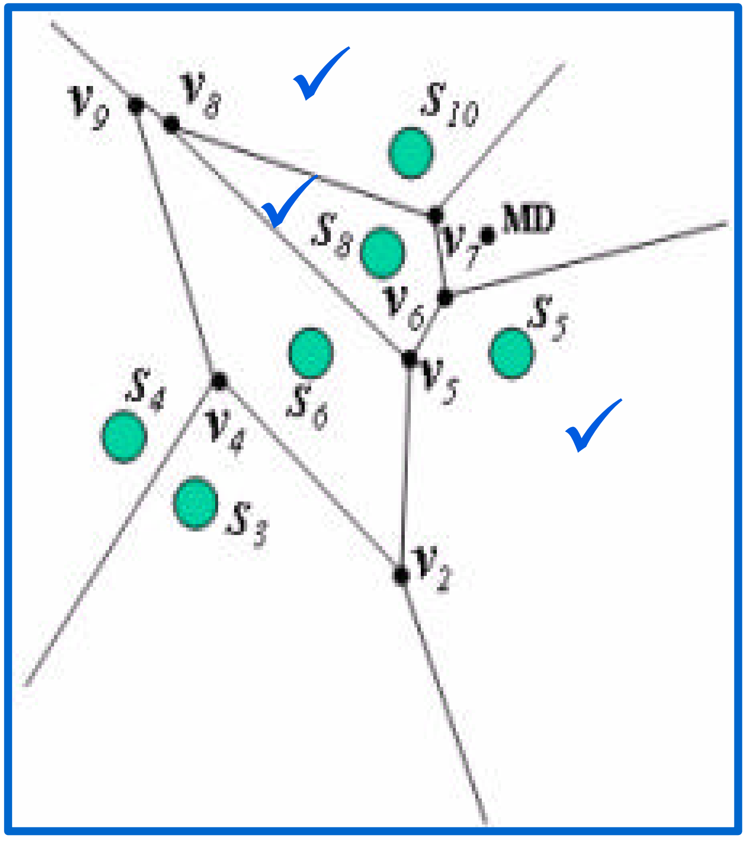
  ***NN($s_6$) = {$s_1$,$s_2$,$s_3$,$s_5$,$s_8$,$s_9$,$s_{10}$}***

  ***NN($s_9$) = {$s_1$,$s_3$,$s_4$,$s_6$,$s_7$,$s_8$,$s_{11}$}***

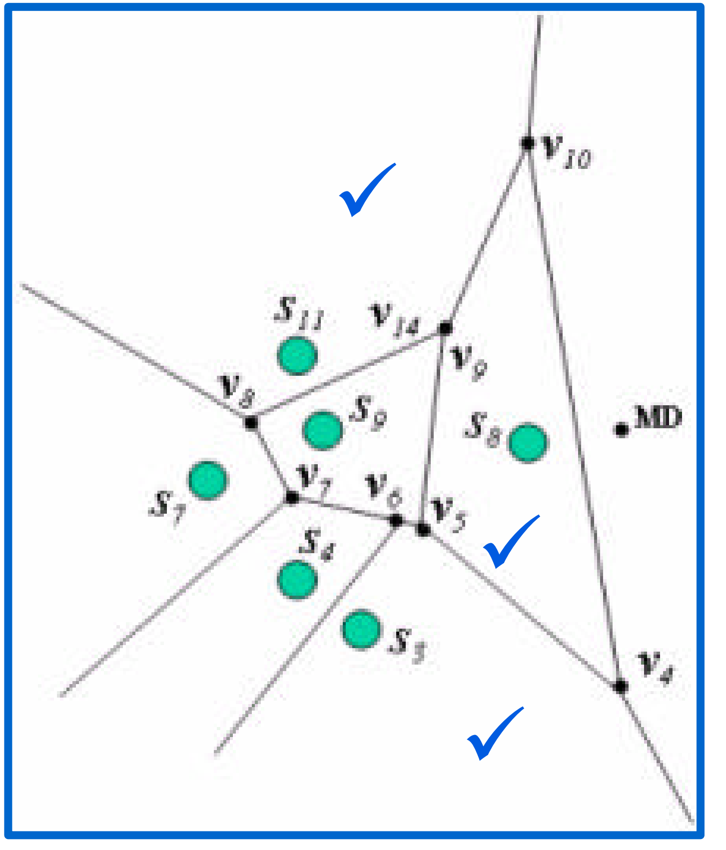



***$VG_{s_1}$***

# Illustrative Example (cont'd)



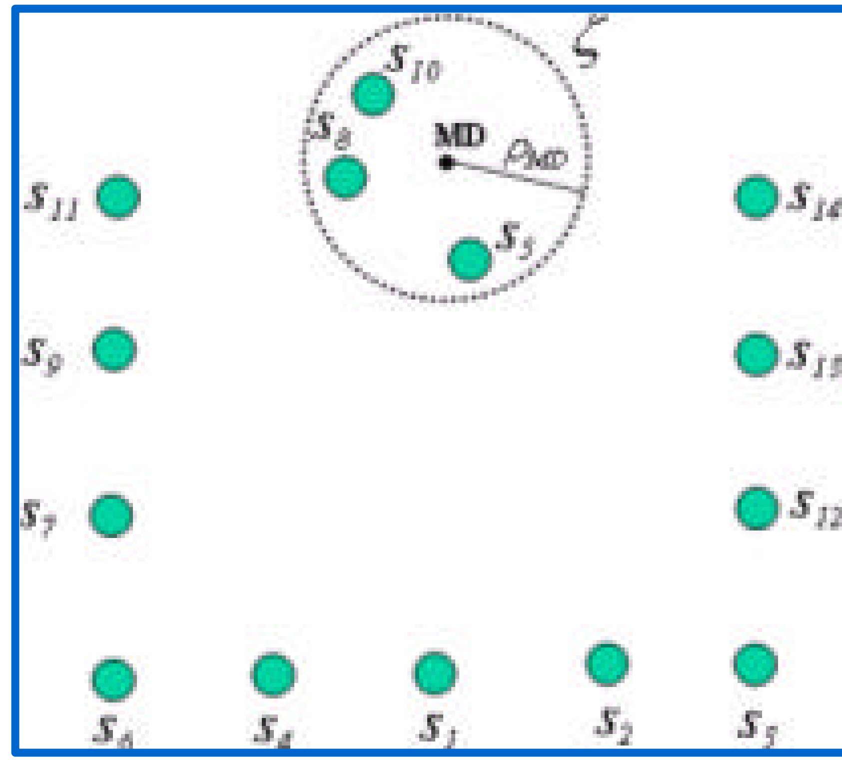

$VG_{s6}$



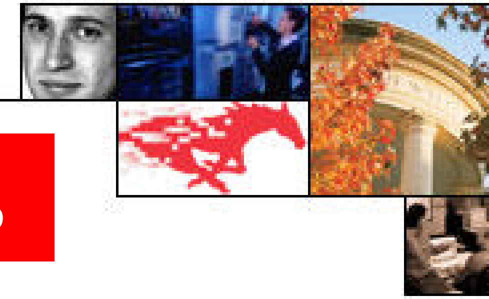

$VG_{s9}$

# Illustrative Example (cont'd)

- Location-based multicast (geocasting) provided by Y. Ko and N. Vaidya: efficient geographical multicast protocol for MANETs
- Their algorithm is based on location and distances between mobile nodes
- It fails in case of blank space between source and multicast domain

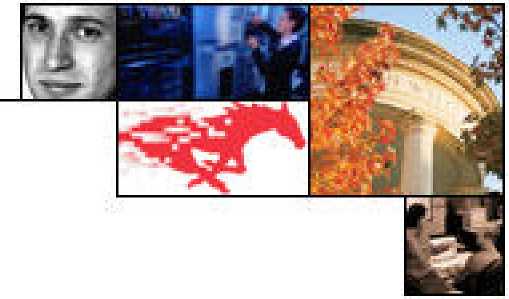



Blank space between source and multicast domain



# Summary and Perspectives

- Multicast protocol for mobile ad hoc networks
- Location information and structural properties of Voronoi diagrams (authorized forwarders to reduce the routing overhead)
- Mathematical analysis of the proposed protocol
- Simulation of the proposed protocol using different mobility models (RWP, RPGM)
- Using this protocol in the integration of the MANETs and the global Internet (providing mobile services)



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Y. Ko and N. Vaidya, "Geocasting in Mobile Ad hoc Networks: Location-Based Multicast Algorithms," *Second IEEE Workshop on Mobile Computer Systems and Applications*, New Orleans, Louisiana, USA, February 25-26, 1999

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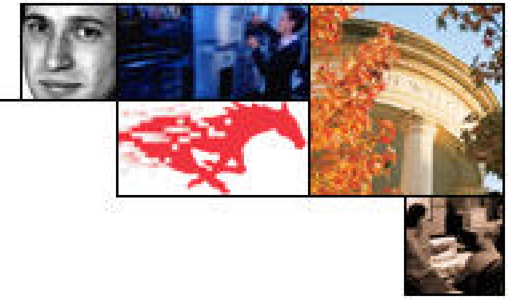

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*** Work supported by the Department of Defense (DoD)**


*Thank you!*

*Questions?*