RELIABLE BROADCAST IN MOBILE MESH NETWORKS

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OUTLINE

- NETWORKING OBJECTIVES
- MILITARY TACTICAL NETWORKING
- TYPICAL NETWORK TOPOLOGIES
- BROADCAST TOPOLOGY
- BROADCAST PROTOCOL
- SUMMARY OF FUTURE WORK

MOBILE COMPUTING NETWORK OBJECTIVES

RELIABLE INFORMATION TRANSFER

- **VOICE/DATA/VIDEO/IMAGERY**
- **COMPLETE/TIMELY**
- **FAULT TOLERANT SERVICES**

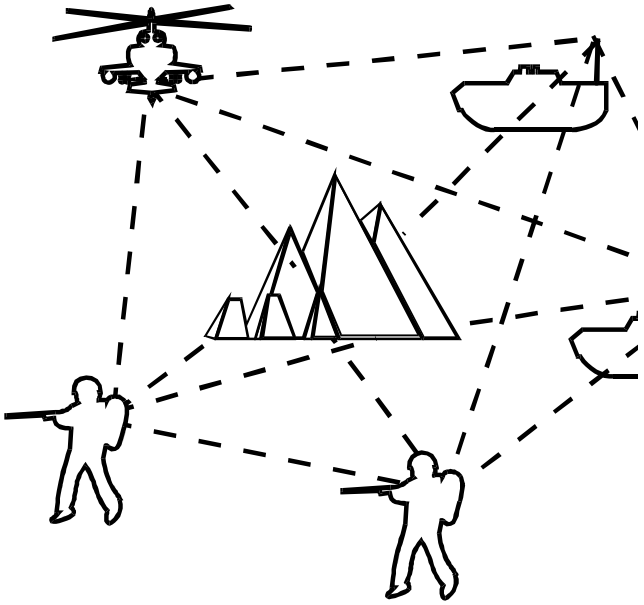
LOW WEIGHT/VOLUME INSTRUMENT

- **PORTABLE POWER**
- **LOCAL MEMORY (DISK & RAM)**

NOMADIC USERS/HOSTS

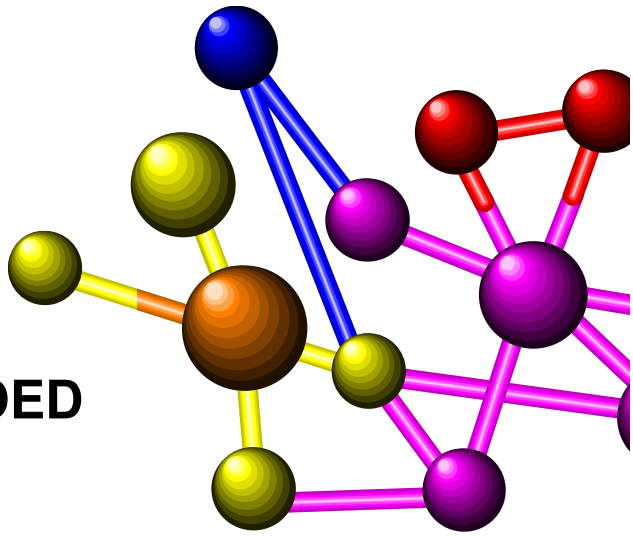
- **RELATIVE HOST LOCATIONS UNKNOWN**

OPERATION OVER IRREGULAR TERRAIN



MOBILE COMPUTING NETWORK OBJECTIVES (cont)

- OPERATE WITHOUT FIXED INFRASTRUCTURE
- MOVE WITH THE SUBSCRIBERS
- MAKE NETWORK SERVICES DYNAMICALLY SCALABLE
- PLACE INFORMATION WHERE NEEDED
- SUPPORT CAUSAL ORDERING
- REDUCE RFI AND RF FRATRICIDE
- OPERATE WITH LOW PROBABILITY OF INTERCEPT



MILITARY TACTICAL NETWORKS

- **MOBILE SUBSCRIBER EQUIPMENT (MSE)**
  - **CELLULAR VOICE**
  - **FLOOD ROUTING**
- **ENHANCED POSITION LOCATION SYSTEM (EPLRS**
  - **PACKET SWITCHING NETWORK**

FIXED INFRASTRUCTURE

LOW CAPACITY & MOBILITY

HIGH POWER, WEIGHT, VOLUME

SIGNIFICANT NETWORK PLANNING SUPPORT

NOMADIC BROADCAST NETWORK ENVIRONMENT

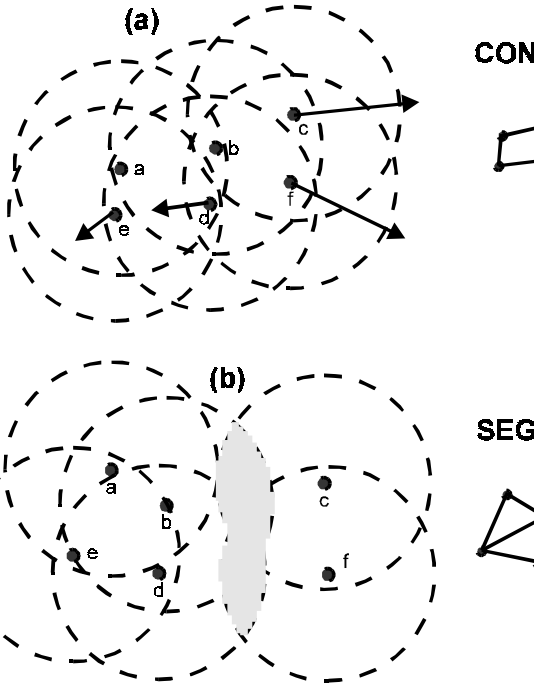
DYNAMIC NETWORK TOPOLOGY

- STOCHASTIC LINK FAILURES
- MULTIPATH FADING
- POWER LAW MODEL: $(1/R)^m$
  - » $2<m<5$

TRANSIENT NETWORK MEMBERSHIP

INTERFERENCE

- THREATS
- FRATRICIDE



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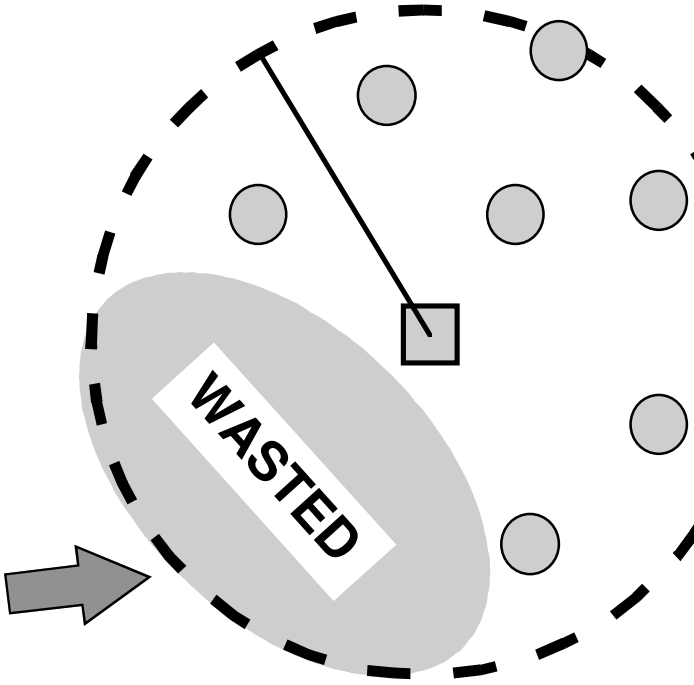
RF NETWORK TOPOLOGIES
SINGLE-HOP

FEATURES

- **POTENTIALLY LOW DELAY**
- **"RELIABLE" DATA TRANSFER**

ISSUES

- **HIGH POWER PER UNIT AREA PER UNIT BIT RATE**
- **HIGH PORTABLE POWER RQMNT**
- **LOW CAPACITY**
- **HIGH RESOURCE CONTENTION**
- **BROADCAST PLACES INFO WHERE NOT NEEDED**
- **FREQUENCY COORDINATION**
- **LIMITED SCALABILITY**



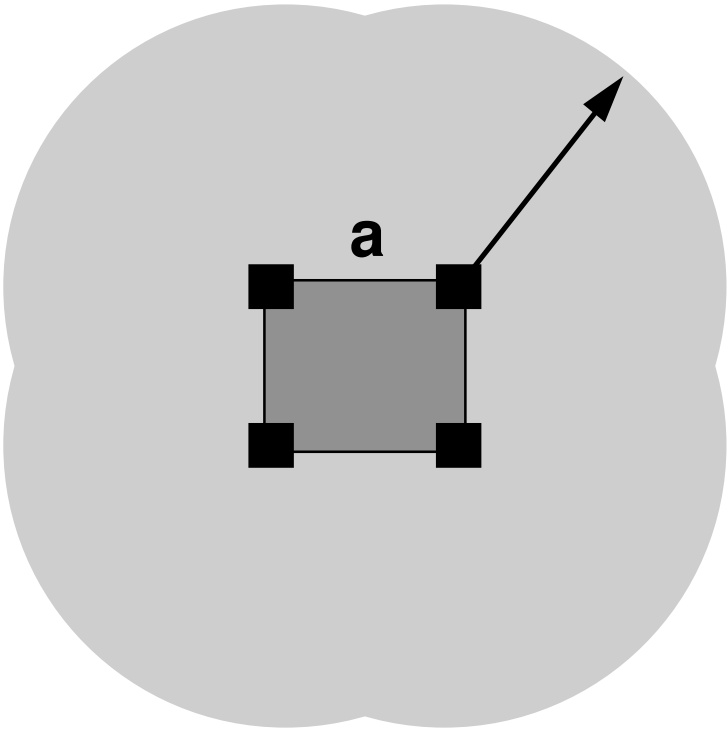
RF NETWORK TOPOLOGIES
SINGLE-HOP COVERAGE

$$A \approx \left(a + 2\sqrt{2}a\right)^2$$

$$\approx \left(a + 2\sqrt{2}a\right)$$

$$c = \left(\frac{\lambda}{4\pi}\right)^2 \frac{G_t G_r}{R^m} P_{tx} \geq P_{sens}$$

$$\leq m \leq 5$$



REQUIRED TX POWER SCALES AS: AREA$^{m/2}$

RF NETWORK TOPOLOGIES

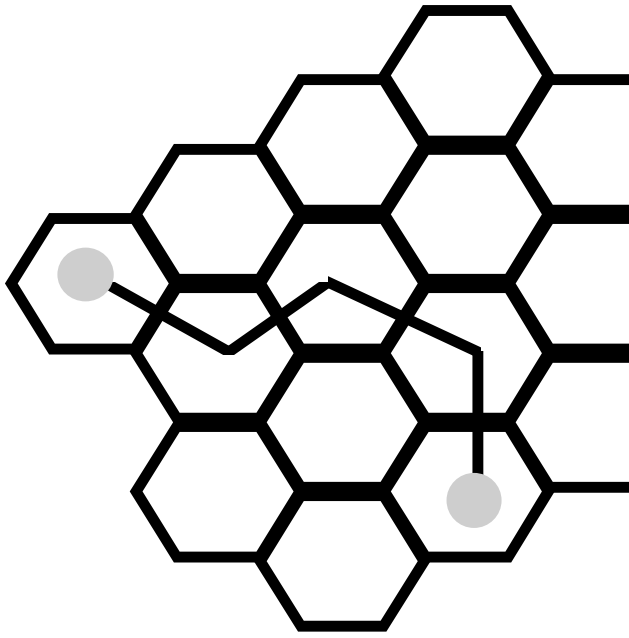
MULTI-HOP

POTENTIAL FOR

- LOW PORTABLE POWER
- LOW PROBABILITY OF INTERCEPT
- INFO PLACED WHERE NEEDED
- GREATER “LOCAL” THROUGHPUT
- LOWER CONTENTION DUE TO SPATIAL REUSE
- LOWER DELAY DUE TO LESS CONTENTION

ISSUES

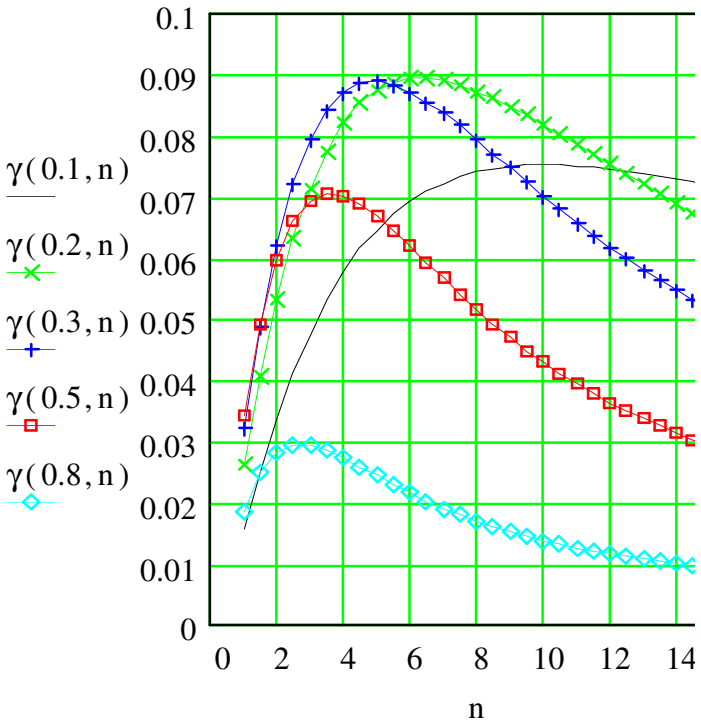
- RELIABLE TRANSPORT
- MULTIHOP DELAY



RF NETWORK TOPOLOGIES
MULTI-HOP

OPTIMUM THROUGHPUT WITH ~ 6 NEIGHBORS

- **SLOTTED ALOHA**
- **MESSAGE ROUTED IN FORWARD DIRECTION**
- **ACCOUNTS FOR HIDDEN NODE COLLISIONS**



R. D. Nelson and L. Kleinrock, “The spatial capa
of a slotted ALOHA multihop packet radio netwo
with capture,” *IEEE Trans. Commun.*, vol. COM
no. 6, pp. 684-694, 1984.

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MESSAGE/DATA ROUTING

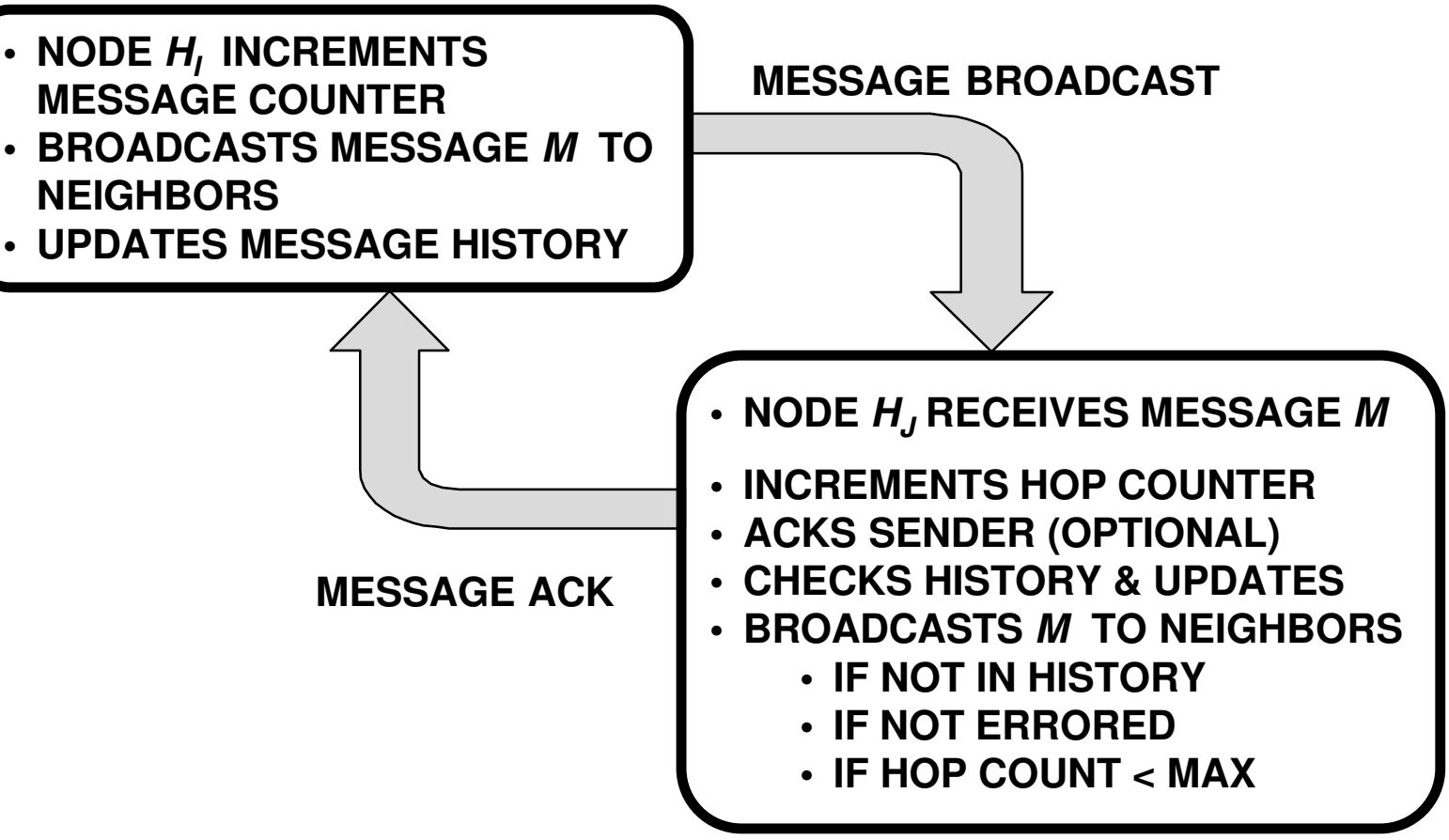
STRUCTURED ROUTING

- TOPOLOGY KNOWN
- DESTINATION LOCATIONS KNOWN
- SUPPORTS ADAPTIVE ALGORITHMS
- USES NETWORK UPDATE OVERHEAD
- SENSITIVE TO SHORT-TERM FAULTS
- MEMBERSHIP KNOWN

• FLOOD ROUTING

- TOPOLOGY UNKNOWN
- DESTINATION LOCATIONS UNKNOWN
- ADAPTIVE ALGORITHMS NOT CURRENT
- NO NETWORK UPDATE OVERHEAD
- RELIABLE DELIVERY
- MEMBERSHIP KNOWN OR UNKNOWN

BROADCAST PROTOCOL



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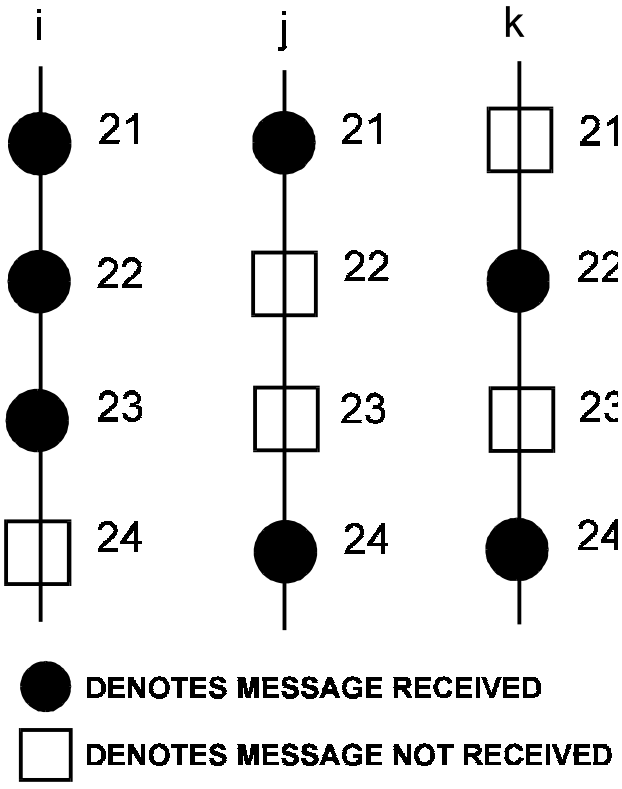
ACKNOWLEDGMENT POLICIES

- **HOP-BY-HOP**
  - **ERROR-FREE MSGS**
    - » **BROADCAST**
    - » **SENDER ACKED**
    - » **HISTORY UPDATED**
  - **ERRORED MSGS**
    - » **SENDER NACKED**
    - » **HISTORY NOT UPDATED**
- **END-TO-END**
  - **ERROR FREE MSGS**
    - » **BROADCAST**
    - » **ACKED IF DESTINATION**
    - » **HISTORY UPDATED**
  - **ERRORED MSG**
    - » **DISCARDED IF NOT DESTINATION**
    - » **NACKED IF DESTINATION**
    - » **HISTORY NOT UPDATED**

MESSAGE HISTORY

- $HOST_J$ HAS RECEIVED 21 & 24 BUT NOT 22 & 23
- $HOST_K$ HAS RECEIVED 22 & 24 BUT NOT 21 & 23
- $HOST_I$ BROADCASTS #21
  - H_J WILL DISCARD *M*
  - H_K WILL RECEIVE *M*, UPDATE, REBROADCAST
- HOP COUNT AND LIFETIME LIMIT REBROADCAST OF *M*



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CONCLUSIONS & FUTURE WORK

- **BROADCAST PROTOCOLS PROVIDE RELIABLE MESSAGE & DATA DELIVERY WITH LOW-POWER INSTRUMENTS**
- **SIGNIFICANT INCREASES IN POWER DOES NOT PROVIDE CORRESPONDING PERFORMANCE INCREASE**
- **MULTI-HOP NETWORKS LIMIT RF "SPILLAGE"**
- **CONTINUING RESEARCH:**
  - **SUPPORT FOR CAUSAL ORDERING**
  - **END-TO-END vs HOP-BY-HOP ACKNOWLEDGMENT**
  - **LIMITING TRAFFIC BY HOP-COUNT AND/OR MESSAGE LIFETIME CONSTRAINTS**