Clustering *vs.* Flooding Protocols

Mohit Garg

Guided by:

Prof. R. K. Shyamasundar, TIFR

Prof. D. Manjunath, IITB

Motivation

- Almost all comparison are based on *simulations*
- Simulations are limited in scope
- Need a more generic way of comparing protocols

Thus there is a need for an analytic comparison framework

Ad Hoc Routing Protocols

- Pro-Active
  - *Always* maintain routes to *all* nodes
  - Large *pro-active* overhead
- Reactive
  - Discover routes *On-Demand*
  - Large *reactive* overhead
- Hierarchical
  - *Always* maintain routes to '*nearby*' nodes
  - Discover other routes reactively
  - *pro-active* + *reactive* overhead

Comparison Metric?

- Power Consumption
- End-to-End Delay
- Data Traffic Capacity

All the above depend solely on the ***Overhead***

Defining ‘Overhead’

- Strictly speaking, any packet exchanged other than data packet is an *overhead*
- Divided into three categories:
  - **Pro-Active (Pr)**
    - Due to Link-Status Updates
  - **Reactive (Re)**
    - Due to flooding messages in route discovery
  - **Sub-Optimal Route (SoR)**
    - Computed route may not be optimal
    - The ‘optimality’ of the route may deteriorate with time

Clustering *vs.* Flooding

- **Network A**: Purely Reactive Routing
- **Network B**: Clusters built over and above the reactive approach
- **Sample path based comparison**
  - Identical node locations
  - Identical link-states
  - Identical Source-Destination pairs at all times

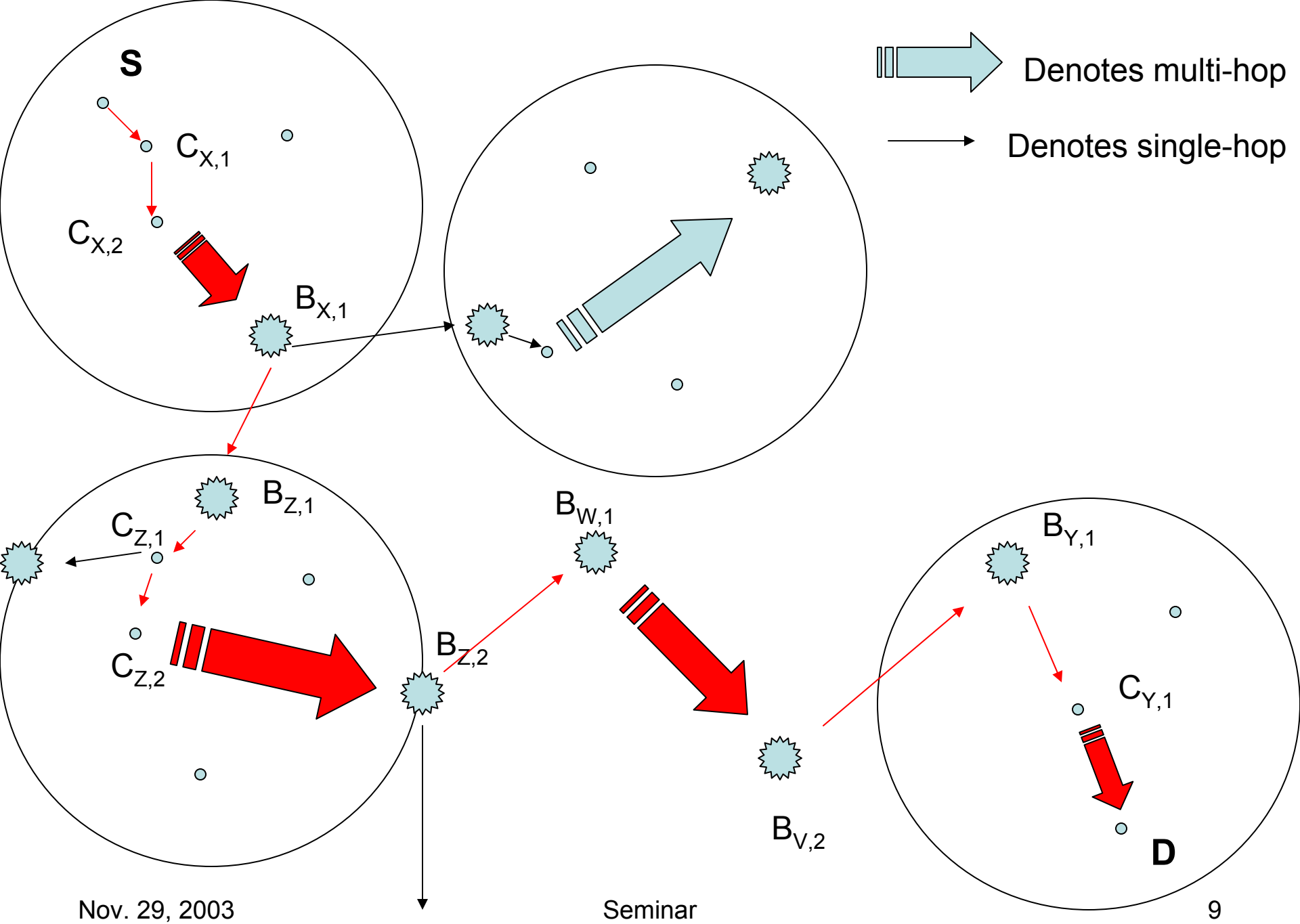
*Will compare **Overheads** under this model*

Model Parameters

- Time interval of observation t_0
- M communicating pairs or flows
- The route for the m^{th} flow is computed R_m times in the observation interval Will show that this is same for both networks since the routes computed are the same
- $\Gamma_A^{k,m}$ flooding messages exchanged for the k^{th} computation of the m^{th} flow in network A. Similarly, $\Gamma_B^{k,m}$

Identical Routes in A and B…

- Same reactive protocol and metric in both
- The ***optimal*** route is unique
- Network A finds the **optimal** route
- In Network B
  - Both S and D belong to *same* cluster –
    - optimal route already known
  - S and D belong to *different* clusters –
    - optimal route computed through border nodes


S
$C_{X,1}$
$C_{X,2}$
$B_{X,1}$
$B_{Z,1}$
$C_{Z,1}$
$C_{Z,2}$
$B_{Z,2}$
$B_{W,1}$
$B_{V,2}$
$B_{Y,1}$
$C_{Y,1}$
D
Denotes multi-hop
Denotes single-hop

Comparing 'Overheads'…

- Thus, $SoR_B = SoR_A$
- Clustering will be better if

$$Pr_B + Re_B \leq Pr_A + Re_A$$

i.e.,

$$Ct_0 + \sum_{m=1}^{M} \sum_{k=1}^{R_m} \Gamma_B^{k,m} \leq 0 + \sum_{m=1}^{M} \sum_{k=1}^{R_m} \Gamma_A^{k,m}$$

… Comparing 'Overheads'…

$$\Rightarrow Ct_0 \le \sum_{m=1}^{M} \sum_{k=1}^{R_m} \left(\Gamma_A^{k,m} - \Gamma_B^{k,m} \right)$$

$$\Rightarrow Ct_0 \le \sum_{m=1}^{M} \sum_{k=1}^{R_m} \sum_{i=1}^{N^{k,m}} \left(\Gamma_i^{k,m} - \Phi_i^{k,m} \Gamma_i^{k,m} \right)$$

$$\approx Ct_0 \le \sum_{m=1}^{M} \sum_{k=1}^{E(R_m)} \sum_{i=1}^{E(N_c)} \left(\Gamma_i^{k,m} - \Phi_i^{k,m} \Gamma_i^{k,m} \right)$$

… Comparing 'Overheads'

$$= Ct_0 \le \sum_{m=1}^{M} \sum_{k=1}^{E(R_m)} \sum_{i=1}^{E(N_c)} \left(\Gamma_i^{k,m} - \Phi_i^{k,m} \Gamma_i^{k,m} \right)$$

$$\Rightarrow E(Ct_0) \le \sum_{m=1}^{M} \sum_{k=1}^{E(R_m)} \sum_{i=1}^{E(N_c)} \left(E(\Gamma_i^{k,m}) - E(\Phi_i^{k,m} \Gamma_i^{k,m}) \right)$$

Using this equation, we can compare the overheads

An interesting observation

$$E(Ct_0) \le \sum_{m=1}^{M} \sum_{k=1}^{E(R_m)} \sum_{i=1}^{E(N_c)} \left(E(\Gamma_i^{k,m}) - E(\Phi_i^{k,m} \Gamma_i^{k,m}) \right)$$

- As *M* increases, RHS changes non-decreasingly
- LHS depends only on the *topological sample path* and hence remains constant with changing *M*
- Thus, there exists a threshold w.r.t no. of communicating pairs (*M*) after which clustering is more suitable than purely reactive routing

Characterising the Variables

- Many random variables in the above analysis
  - R_m : No. of times the m^{th} flow route is computed
  - $\Gamma_i^{k,m}$: No. of flooding packets in the i^{th} cluster in *A*
  - $\Phi_i^{k,m}$: Fraction of nodes (w.r.t. $\Gamma_i^{k,m}$) flooding in the i^{th} cluster in *B*
  - C : Cluster maintenance overhead
- Difficult to say anything in general
- Stationarity *w.r.t.* k and m can be assumed
- Detailed analysis needs more information about the protocols and network conditions

Conclusion

- A general framework was developed to compare clustering and flooding protocols
- Analytical calculations can be done without simulating the entire scenario
- Clustering scores over flooding if data traffic is above a threshold