Link Stability-based Routing and Clustering in Ad Hoc Wireless Networks Using Fuzzy Set Theory

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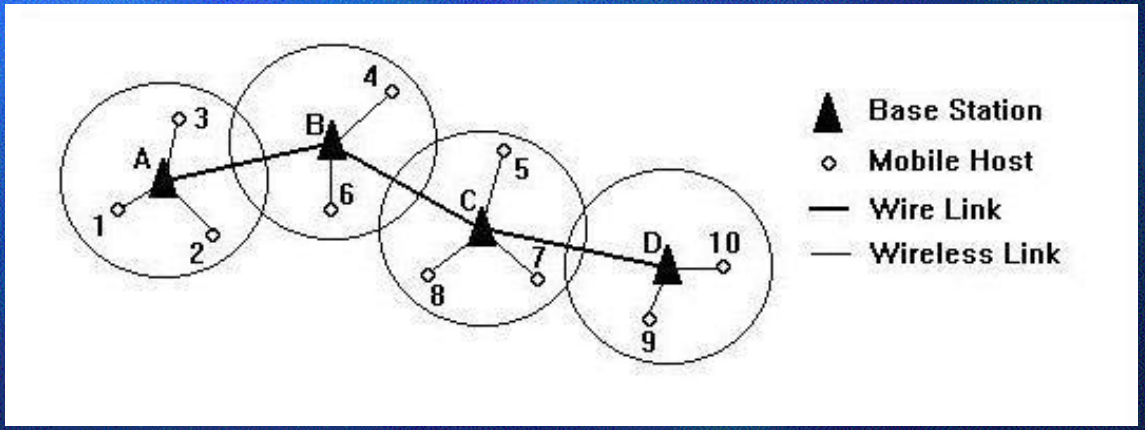
Agenda

- Related researches
  - Hop by hop routing: Link state, distance vector and sour routing based.
  - Routing algorithm: Table driven, On demand, Hybrid. Like as DSDV, AODV, DSR, ZRP.
  - Cluster architecture and algorithm: HC, LID.
- Present stage of research
  - LSC(Link Stability-based Clustering).
  - LSR(Link Stability-based Routing).
- Simulation
  - Clustering: re-clustering, average cluster.
  - Routing: path life time, hopping, dropping probability.
- Conclusion

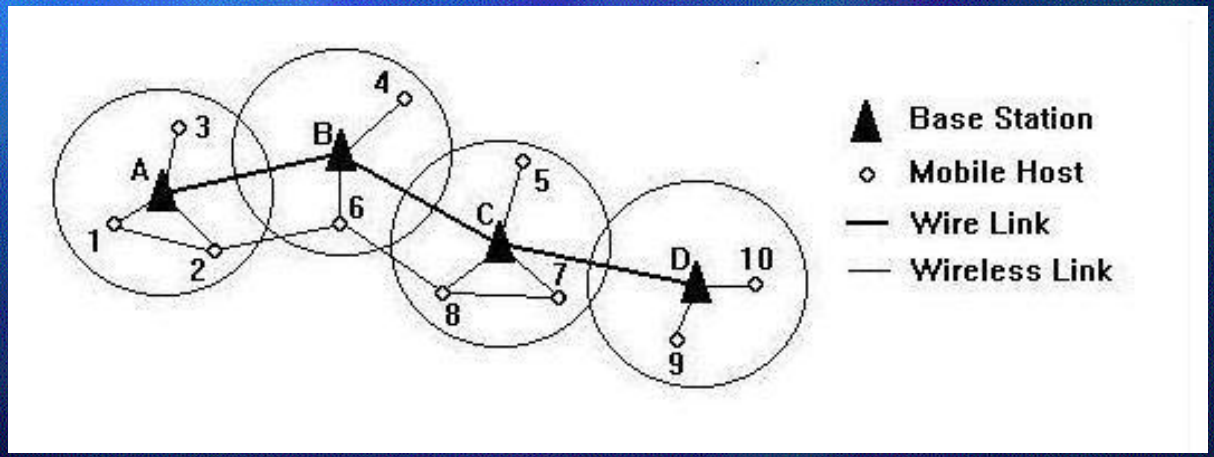
Related researches

- **Single hop**
  - Advantages: BS access network information and route computing. MH just sent and received messages.
  - Disadvantages : Any communication need BS's help. The neighbor's MH need BS help but, can not direct communication. If one BS in one cell fails, those MH can not communicate each other in the BS transmission range.



Related research(cont.)

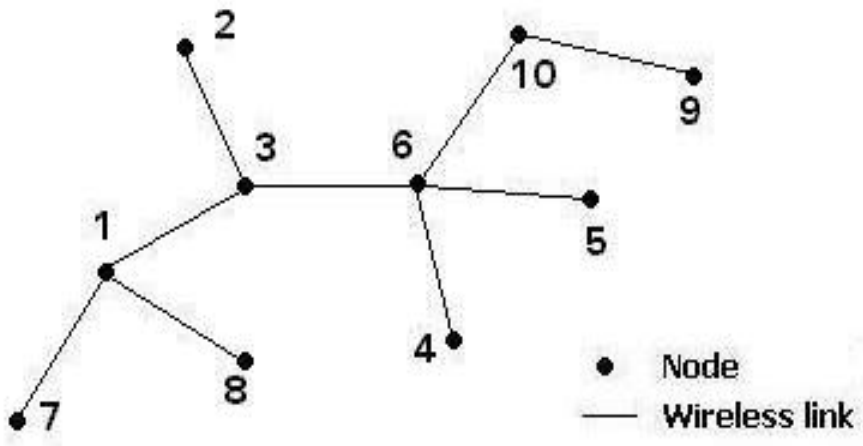
- **Multi hop**
  - Advantages: In the transmission range between two MHs. They can communicate each other without BS supported. When some BSs fail they can use the hop by hop scheme to communication via neighbor nodes to transfer message.
  - Disadvantages :The more intermediate nodes needed will increase work load and need more bandwidth.



Related research(cont.)

- **Hop by hop routing (point to point)**
  - **Link State based**

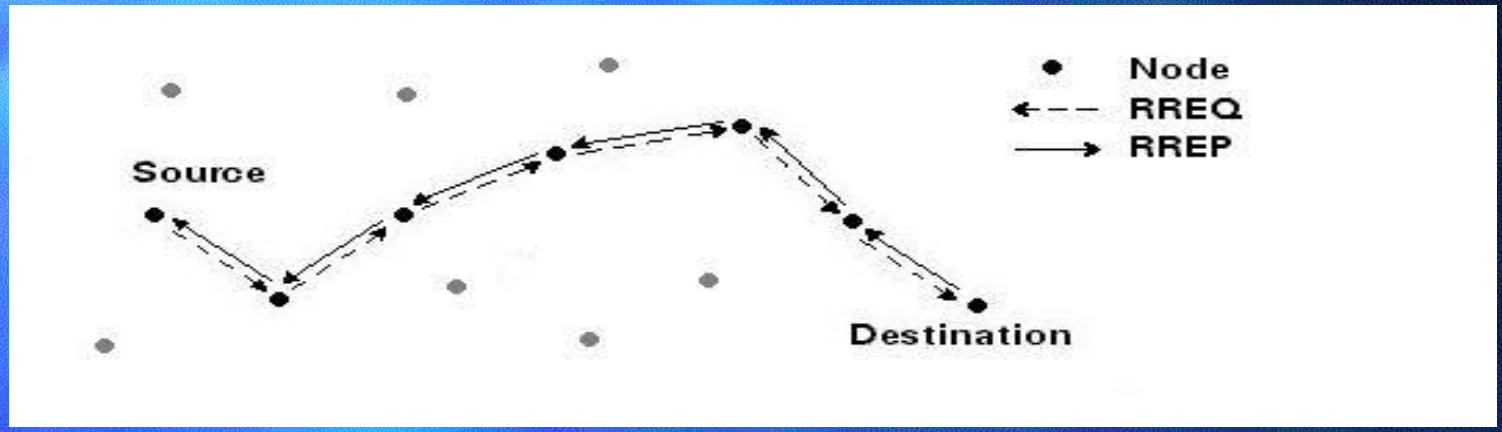
    All link table of node in network with Shortest path or Vertex cover, Bellmen Ford algorithm.
  - **Distance Vector based**

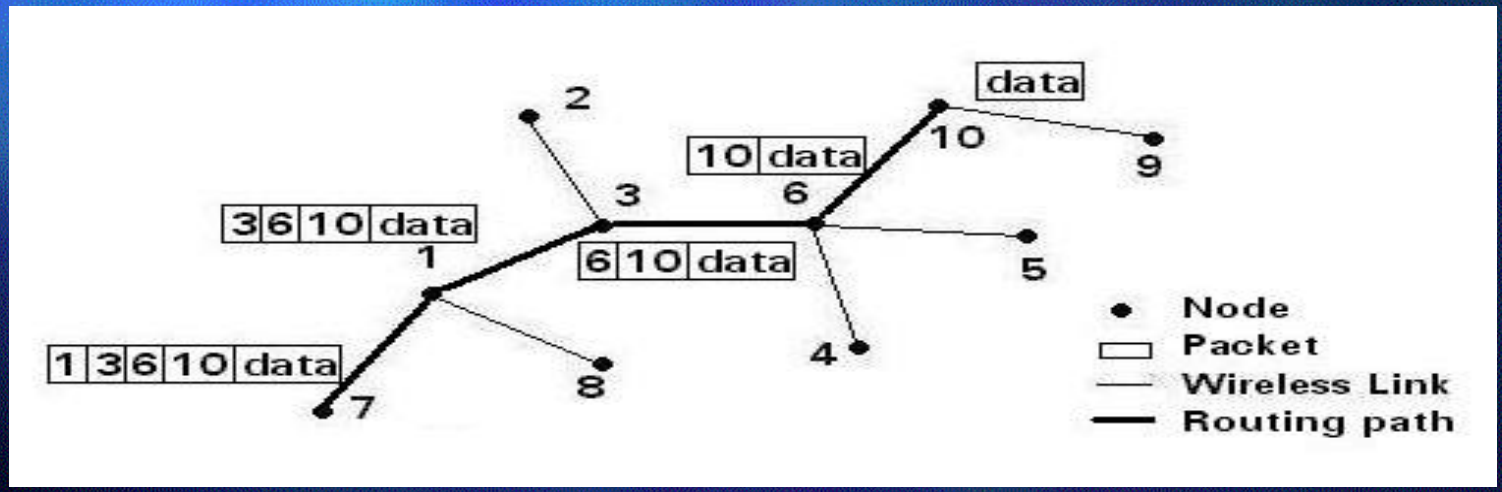


Destination	Next Hop	Metric
1	3	2
2	3	2
3	3	1
4	4	1
5	5	1
6	6	0
7	3	3
8	3	3
9	10	2
10	10	1

Related research (cont.)

- Source Routing based





Related research (cont.)

- **Routing information**
  - **Proactive/Table driven: Frequently update routing table for every node.**
    - **Advantages - Faster getting the route via routing table.**
    - **Disadvantages - Need large memory space and wireless bandwidth. Topology changed cause node's loading become heavy.**
  - **Reactive/On demand: Discover route when needed.**
    - **Disadvantages - Non immediately.**
    - **Advantages - No need to update routing table. Saving memory and bandwidth.**
  - **Hybrid: Combine with proactive and reactive. Faster getting the route, saving memory and saving bandwidth.**

Related research(cont.)

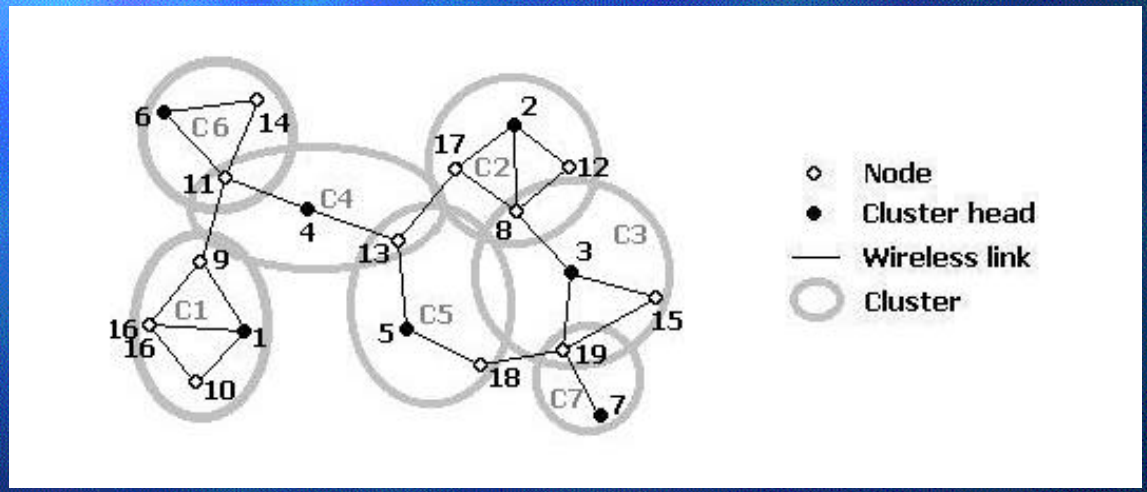
- **Comparison of routing algorithm**

Routing Algorithm	Routing	Scheme
DSDV(Dynamic Sequenced Distance Vector)	Proactive (Table driven)	Distance Vector
AODV(Ad hoc On Demand Distance Vector Routing)	Reactive (On demand)	Distance Vector
DSR(Dynamic Source Routing)	Reactive (On demand)	Source Routing
ZRP(Zone Routing Protocol)	Hybrid	Hybrid
LSR(Link Stability Routing)	Hybrid	Hybrid

Related research (cont.)

- **Clustering & Re-Clustering**
- **Lowest ID clustering algorithm (LID)**

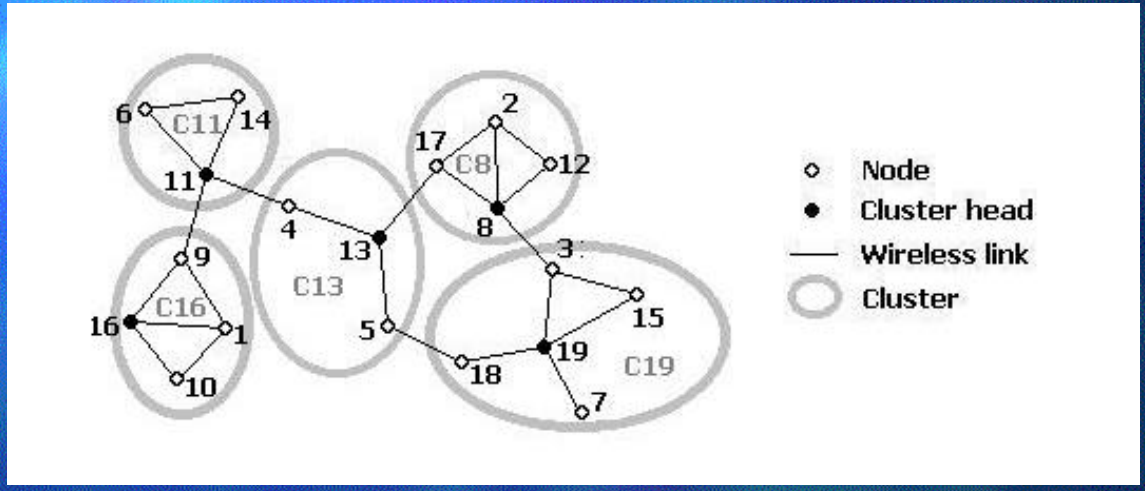
  When clustering and the lowest ID is chosen as the cluster head. The unique ID property for every mobile host.



Related research (cont.)

- **High Connectivity clustering algorithm (HC)**

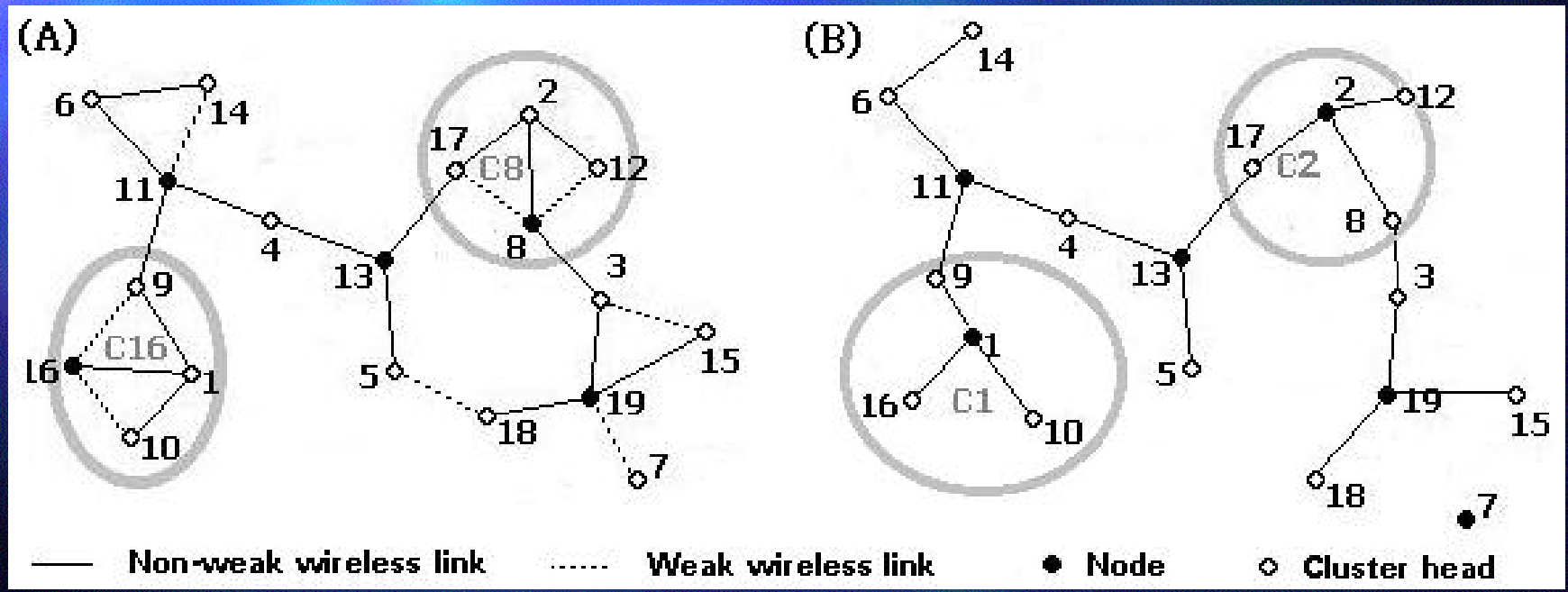
  The node has the maximum degree to be the cluster head. The other neighbors are as cluster member.



Present stage of research (cont.)

- **The effect of Re-clustering**

  Bad clustering algorithm will cause re-clustering frequency too many, and then increase node‘ loading too heavy and waste wireless bendwidth.



Present stage of research (cont.)

- **Strategy of re-clustering reduce**
  - Number of Cluster head reduced

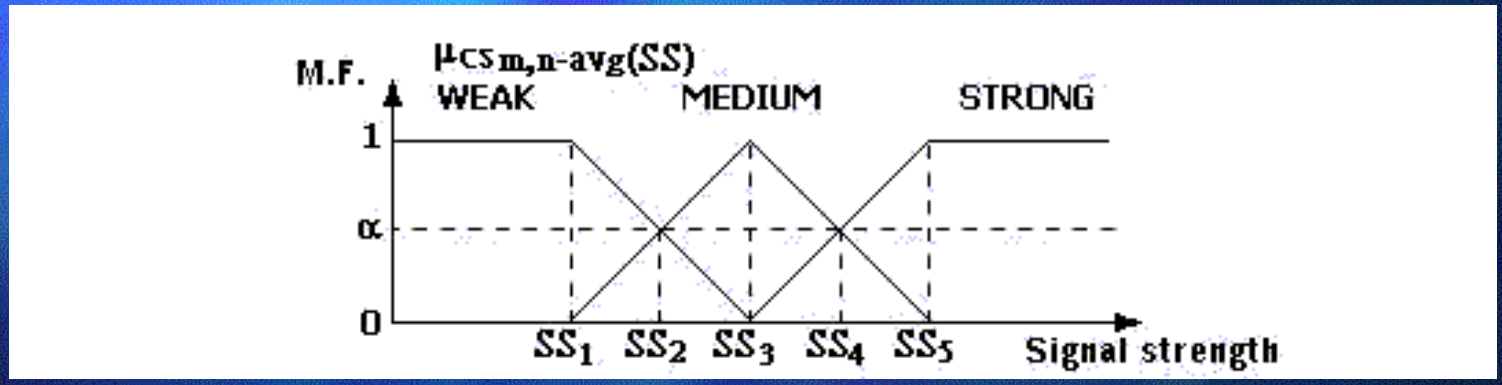
    May increase the number of hopping in cluster and cause cluster head's loading too heavy and low performance.
  - **Reliability-based cluster head selection algorithm**

Present stage of research (cont.)

- **Link Stability-based Clustering algorithm**
- **Definition :**

  $CS_{m,n\text{-}avg}(SS)$ **is average signal strength relation of the connect from node m to n.**

  Fuzzy set as WEAK, MEDIUM, STRONG.



Present stage of research (cont.)

- **Free space propagation model**

  The model is used to predict the received signal strength as following Friis free space equation.

  ☞ $P_r(d) = (P_t G_t G_r \ ^2)/[(4\ )^2 d^2 L]$

  $P_r(d)$: Receiver power
  G_r : Receiver antenna gain
  P_t : Transmitted power
  G_t : Transmitter antenna gain
  : Wavelength in meters
  L : System loss factor
  d : Distance from transmitter to receiver

Present stage of research (cont.)

- **Path loss**

  The path loss for free space model as following equation.

  - $PL(dB) = 10 \log (P_t/P_r) = -10 \log [\ ^2 /(4 \ )^2 d^2]$
    $= -10 \log(G_t G_r \ ^2)/[(4 \ )^2 d^2]$
  - $= c/f_c = 2 \ c/ \ _c$
  - $_c = 1/2 \ f_c$

  c : Speed of light

  f_c : Carrier frequency

  $_c$: Carrier frequency in radians per second

Present stage of research (cont.)

- **Fuzzify**
  - SS_1 denoted d=transmission range and measured the signal strength as $P_r(D)$.
  - SS_2 denoted d= 3/4 transmission range and measured the signal strength as $P_r(3/4D)$.
  - SS_3 denoted d= 1/2 transmission range and measured the signal strength as $P_r(1/2D)$.
  - SS_4 denoted d= 1/4 transmission range and measured the signal strength as $P_r(1/4D)$.
  - SS_5 denoted transfer and receiver at same location and measured the signal strength as $P_r(1)$.

Present stage of research (cont.)

- **Membership function**
  - .Relation of signal strength $_{CSm,n\text{-}avg}(SS)$ is WEAK

$$\begin{cases} 1 & ,SS_{avg} \ \ SS_1 \\ SS_3 - SS_{avg}/SS_1 & ,SS_1 < SS_{avg} < SS_3 \\ 0 & ,SS_{avg} \ \ SS_3 \end{cases}$$

  - . Relation of signal strength $_{CSm,n\text{-}avg}(SS)$ is MEDIUM

$$\begin{cases} SS_5 - SS_{avg}/SS_1 & , SS_3 \ \ SS_{avg} < SS_4 \\ SS_{avg} - SS_1/SS_1 & ,SS_1 < SS_{avg} \ \ SS_3 \\ 0 & ,SS_{avg} \ \ SS_1 \text{ or } SS_{avg} \ \ SS_5 \end{cases}$$

  - . Relation of signal strength $_{CSm,n\text{-}avg}(SS)$ is STRONG

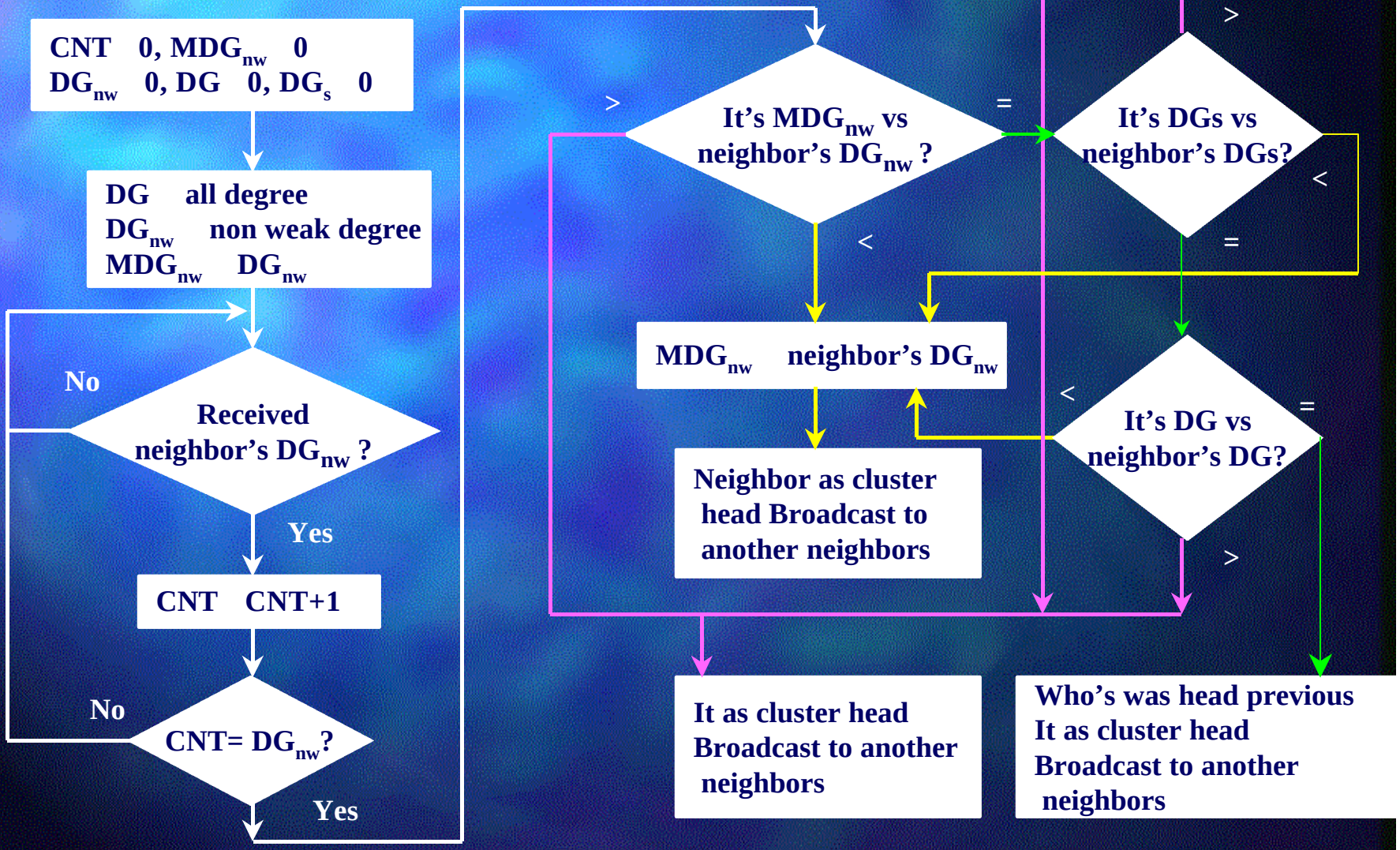
$$\begin{cases} 1 & ,SS_{avg} \ \ SS_5 \\ SS_{avg} - SS_3/SS_1 & ,SS_3 < SS_{avg} < SS_5 \\ 0 & ,SS_{avg} \ \ SS_3 \end{cases}$$

Present stage of research (cont.)

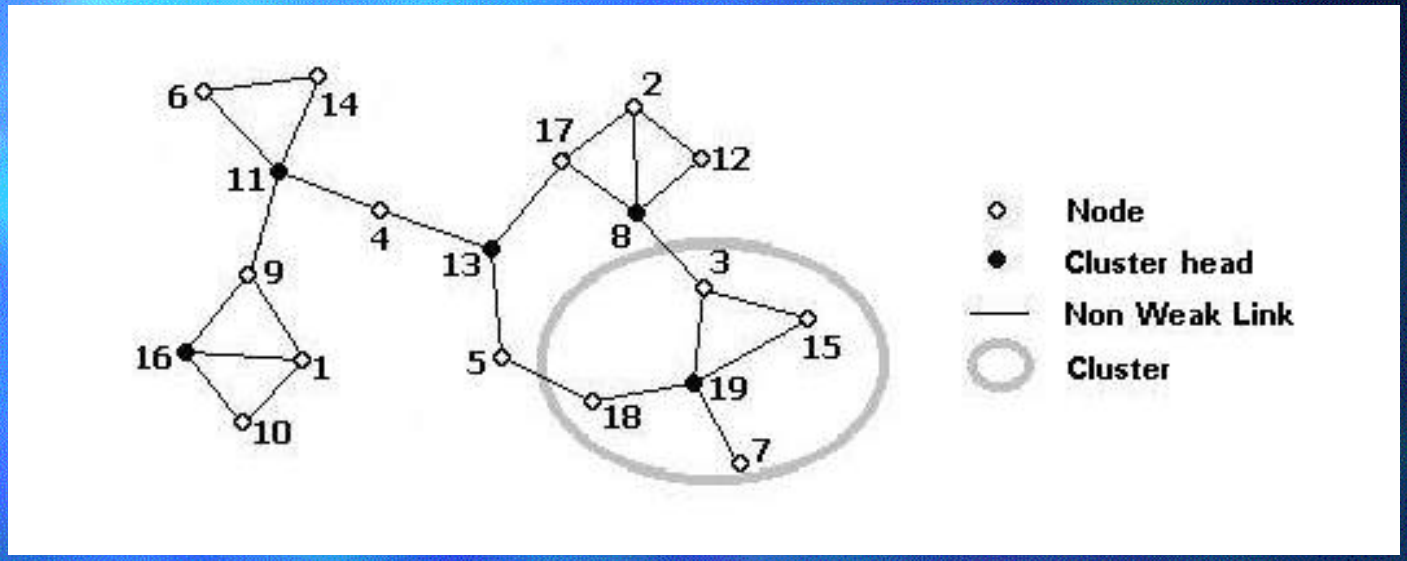
- **Parameters**
  - ☞ ***CNT*** **: Counting received number of neighbor's degree message.**
  - ☞ ***DG*** **: The maximum connection value of every node.**
  - ☞ $DG_{non\text{-}weak}$ **: The non-weakly connection value of every node.**
  - ☞ $MDG_{non\text{-}weak}$ **: The maximum non-weakly connection value of node and neighbor.**

Present stage of research (cont.)

Flowchart



Present stage of research (cont.)



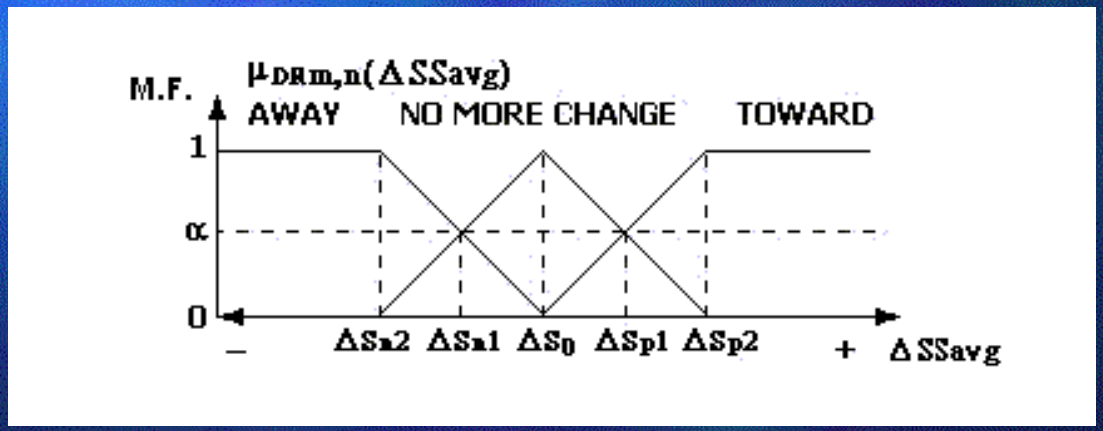
Node number	DG	$DG_{non\text{-}weak}$	$MDG_{non\text{-}weak}$	CH
3	5	3	3,…,(4)	19
19	4	4	(4),2,1,2,3	19
15	3	2	2,(4),3	19
7	2	1	1,(4)	19
18	3	2	2,(4)	19
8	4	4	(4),…,3	8
5	3	2	2,2,(3)	13

Present stage of research (cont.)

- **Link Stability-based Routing Algorithm**
- **Definition**

$DR_{m,n}(SS_{avg})$: Distance relation of the link between node m,n. Fuzzy set as AWAY, NO MORE CHANGE, TOWARD.

Distance relation $SS_{avg} = (SS_{current} - SS_{previous}) / t$



Present stage of research (cont.)

- **Fuzzify**
- If SS_{avg} is Negative and large means distance relation between two nodes is moving away.

  $_{DRm,n}(\ SS_{avg})$ fuzzy set as AWAY.
- If SS_{avg} is very small means distance relation between two nodes like as stay or parallel moving.

  $_{DRm,n}(\ SS_{avg})$ fuzzy set as NO MORE CHANGE.
- If SS_{avg} is Positive and large means distance relation between two nodes is moving toward.

  $_{DRm,n}(\ SS_{avg})$ fuzzy set as TOWARD.

Present stage of research (cont.)

- **Membership function**
  - .Relation of Distance $DRm,n(SS_{avg})$ is AWAY

$$\begin{cases} 1 & , SS_{avg} \quad S_{n2} \\ (S_0 - SS_{avg})/S_{n2} & , S_{n2} < SS_{avg} < 0 \\ 0 & , SS_{avg} \quad 0 \end{cases}$$

  - . Relation of Distance $DRm,n(SS_{avg})$ is NO MORE CHANGE

$$\begin{cases} (S_{p2} - SS_{avg})/S_{n2} & , 0 \quad SS_{avg} < S_{p1} \\ (SS_{avg} - S_{n2})/S_{n2} & , S_{n2} < SS_{avg} \quad 0 \\ 0 & , SS_{avg} \quad S_{n2} \text{ or } SS_{avg} \quad S_{p2} \end{cases}$$

  - . Relation of Distance $DRm,n(SS_{avg})$ is TOWARD

$$\begin{cases} 1 & , SS_{avg} \quad S_{p2} \\ (SS_{avg} - S_0)/S_{n2} & , 0 < SS_{avg} < S_{p2} \\ 0 & , SS_{avg} \quad 0 \end{cases}$$

Present stage of research (cont.)

- **Life time of link**
- **Definition :**

  $LTm,n(lf)$: Exist a link from node m to n. Average signal strength relation and distance relation between two nodes denote the life time. Those two sets's intersection as life time fuzzy set SHORT, MEDIUM, LONG.

  $$LTm,n(lf) = CSm,n\text{-}avg(SS) \times DRm,n(SS_{avg})$$

Present stage of research (cont.)

- **Fuzzy inference engine and Fuzzy rules**

  CFP(Compound Fuzzy Proposition)

  AFP(Atomic Fuzzy Proposition)

  If (FP_1 and FP_2) (FP_3)

  If [$_{CSm,n\text{-}avg}(SS)$ and $_{DRm,n}(SS_{avg})$] $_{LTm,n}(lf)$

  Using Godel or Mamdani combination :

$$Q=\bigcap_{g=1}^{m} R^{(g)} \triangleq Q_G \quad , \quad Q=\bigcup_{g=1}^{m} R^{(g)} \triangleq Q_M$$

  t-based , s-based fuzzy relation

  Using Cartesian product :

  $R^{(g)}=$ $_{CSm,n\text{-}avg}(SS)^{(g)} \times$ $_{DRm,n}(S_{avg})^{(g)}$ $_{LTm,n}(lf)^{(g)}$.

  $R^{(g)}$ g=1,2,3,…,i are if then fuzzy proposition.

Present stage of research (cont.)

Fuzzy rules : $R^{(1)}$~$R^{(9)}$

Fuzzy rules	IF		THEN
	$\mu_{CSmn\text{-}avg}(SS)$	$\mu_{DRmn}(\Delta SS_{avg})$	$\mu_{LDmn}(lf)$
$R^{(1)}$	STRONG	MOVE AWAY	MEDIUM
$R^{(2)}$	MEDIUM	MOVE AWAY	SHORT
$R^{(3)}$	WEAK	MOVE AWAY	SHORT
$R^{(4)}$	STRONG	NO MORE CHANGE	LONG
$R^{(5)}$	MEDIUM	NO MORE CHANGE	MEDIUM
$R^{(6)}$	WEAK	NO MORE CHANGE	SHORT
$R^{(7)}$	STRONG	MOVE TOWARD	LONG
$R^{(8)}$	MEDIUM	MOVE TOWARD	LONG
$R^{(9)}$	WEAK	MOVE TOWARD	MEDIUM

Present stage of research (cont.)

Definitions

- **The stability of the path $P_{i,m}$ Given any path $P_{i,m}=P_{i,j,k,...,m}$ .The life time $LTpi,m(lf)$ of the path is determined by the link i to m.**

  Fuzzy set is SHORT, MEDIUM, LONG.

  $LTpi,m(lf)=\text{Min}\{LTi,j(lf), LTj,k(lf),\ldots, LTl,m(lf)\}$

  $= LTi,j(lf) \quad LTj,k(lf) \quad \cdots \quad LTl,m(lf)$

  Example :

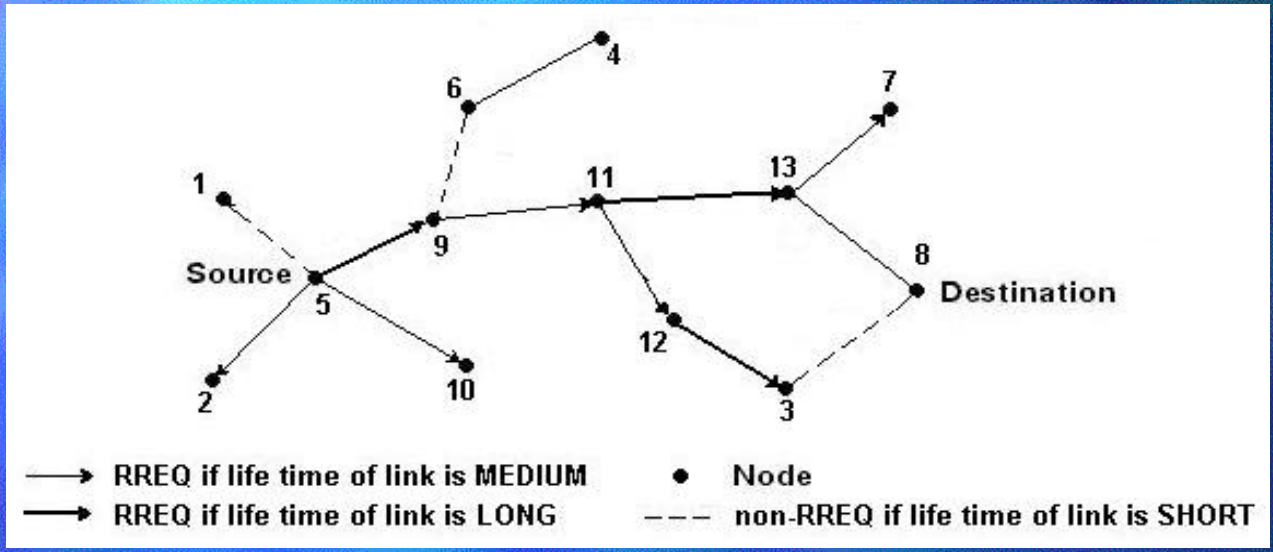
  $LTp_{i,m}(lf)=\text{Min}\{LTg,h(lf), LTh,i(lf), LTi,j(lf), LTj,k(lf)\}$

  $= LTg,h(lf) \quad LTh,i(lf) \quad LTi,j(lf) \quad LTj,k(lf)$

  =MEDIUM LONG LONG MEDIUM

  =MEDIUM

Present stage of research (cont.)



$LT_{5,1}(lf)$. $LT_{9,6}(lf)$, $LT_{3,8}(lf)$ those link's life time is SHORT.

Path 5 9 11 13 8. Life time of the path

$$LTp_{5,8}(lf)=\text{Min}\{LT_{5,9}(lf), LT_{9,11}(lf), LT_{11,13}(lf), LT_{13,8}(lf)\}$$

$$= LT_{5,9}(lf)\ \ LT_{9,11}(lf)\ \ LT_{11,13}(lf)\ \ LT_{13,8}(lf)$$

=LONG MEDIUM LONG MEDIUM

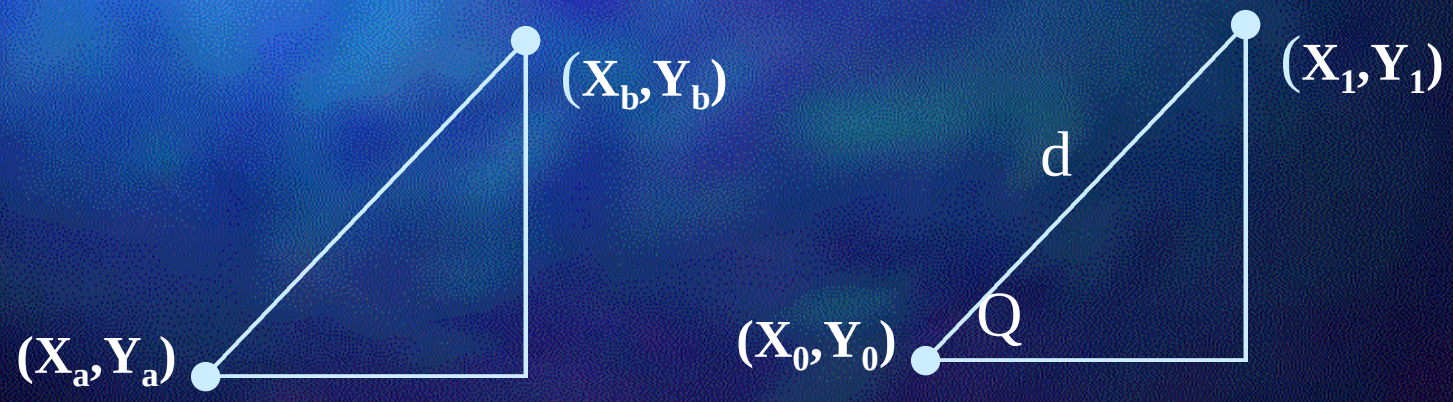
=MEDIUM

Simulation

- **Calculation distance and location principle**
  - (X_0, Y_0) is previous location and (X_1, Y_1) is new location after moved. The moving speeds denote d m/sec and move direction denote angle Q.

    $X_1 = X_0 + \text{Cos}(Q) * d$ $\quad$ $Y_1 = Y_0 + \text{Sin}(Q) * d$
  - One's location is (X_a, Y_a) and the other location is (X_b, Y_b). To Compute distance between two nodes.

$$\sqrt{(X_a - X_b)^2 + (Y_b - Y_b)^2}$$



Simulation (cont.)

- **Simulation environment**
  - Set 100, 150, 200 or 400 node in 1Km^2 square area. The transmission ranges as 50m, 100m, 150m, 200m, 250m.
  - Host move direction randomly with choice random moving speeds between 0~30 m/sec. If a host hit the boundary of the area, it will bounce back.
  - The total re-clustering is lower then stability of cluster is higher. So, simulation of using difference transmission ranges and number of host with randomly moving speeds.

Simulation (cont.)

- **Simulation parameters**
  - **Clustering evaluation**

    To simulate different clustering algorithms like as HC, LID and LSC. Compare with Total of re-clustering ($N_{re\text{-}clustering}$), average cluster($N_{cluster}$).
  - **Routing evaluation**

    To simulate different routing algorithms like as DSR and LSR. Compare life time of the path (LF_{time}), average of hopping ($N_{hopping}$) and dropping probability of RREQ ($P_{dropping}$).

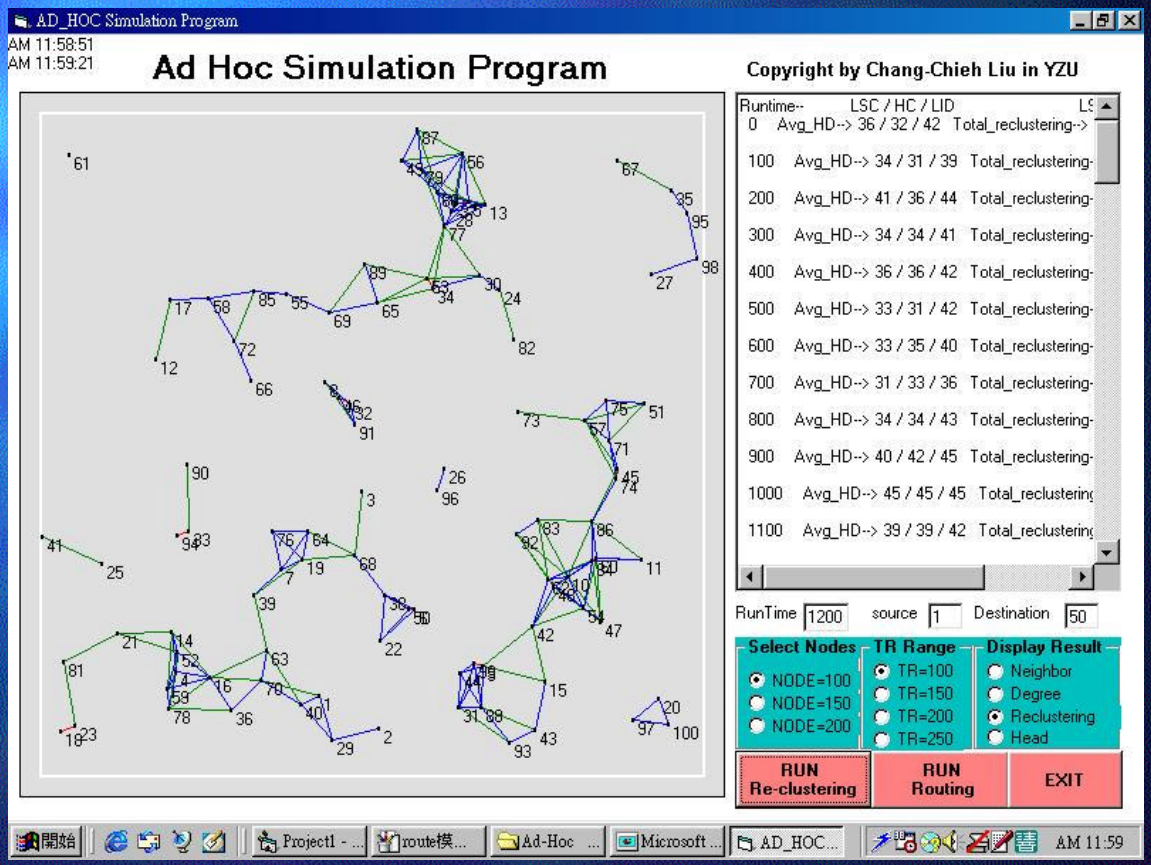
Simulation (cont.)

- **Target**
  - After initial clustering. During time re-clustering once then re-clustering number ($N_{re\text{-}clustering}$) adds one. To prove that using LSC alg. has less re-clustering and less overhead than HC, LID. Simulation by different transmission ranges 50m, 100m, 150m, 200m , 250m.
  - Simulation to prove that using LSR alg. can get high stability path. The LSR has longer life time of path (LF_{time}), and lower dropping probability of route discovery ($P_{dropping}$) than DSR. Simulation by different transmission ranges 50m, 100m, 150m, 200m, 250m.

Simulation (cont.)

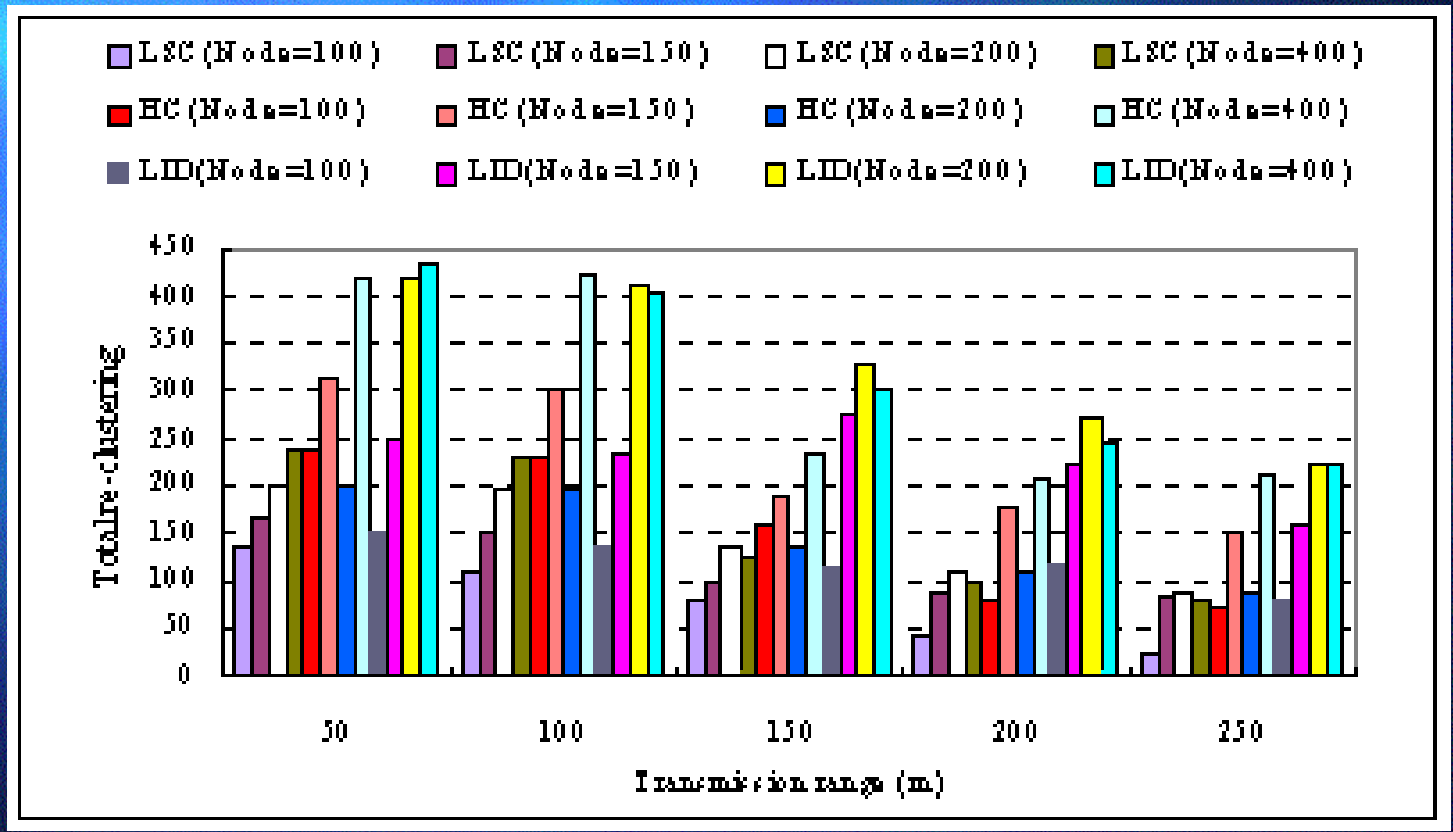
- **Start Clustering simulation**

  Choice same network sizes with different transmission range to simulated total of re-clustering ($N_{re\text{-}clustering}$) and average cluster($N_{cluster}$) in network.



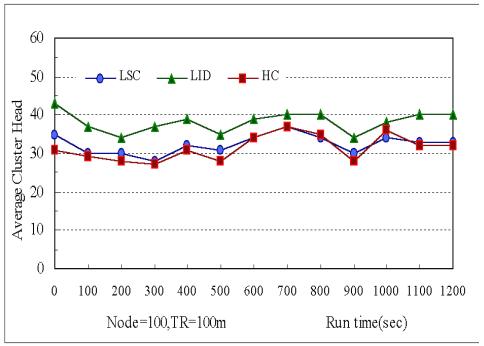
Simulation (cont.)

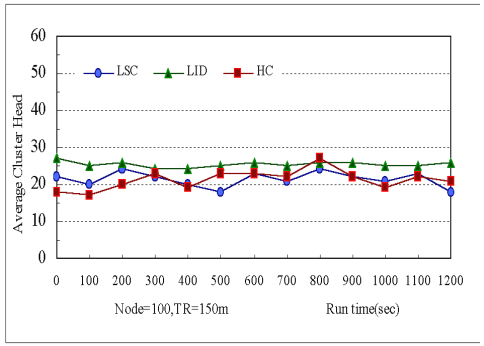
- **Generate Graphics- Compared with total re-clustering**

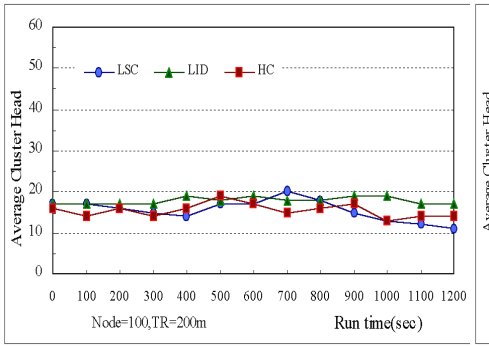


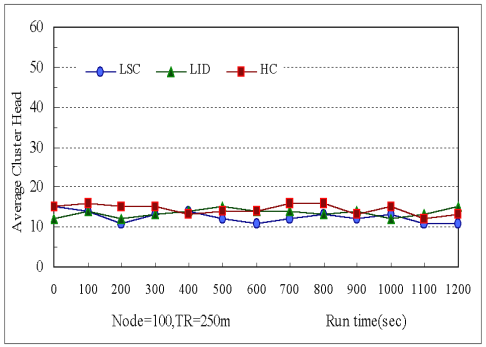
Simulation (cont.)

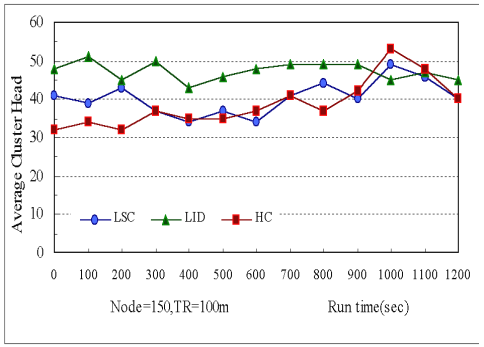
Generate Graphics- Compared with average cluster

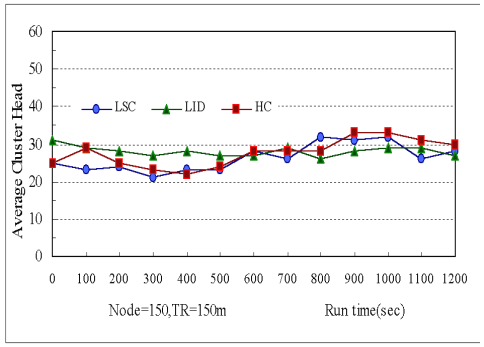


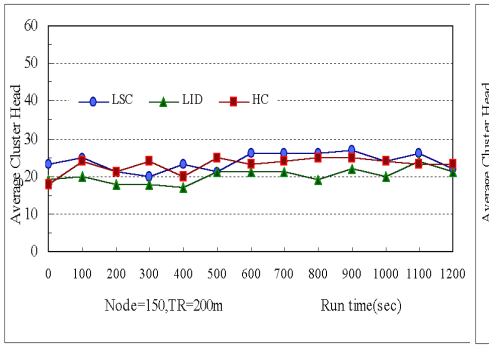


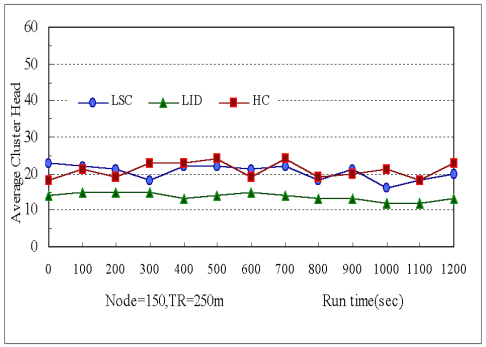


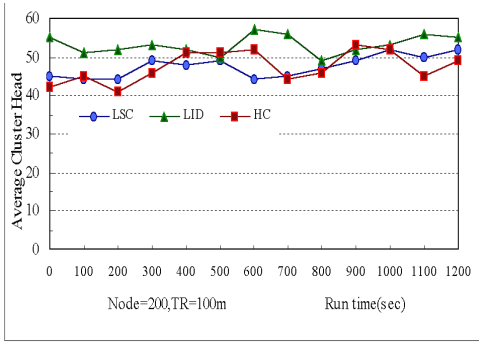


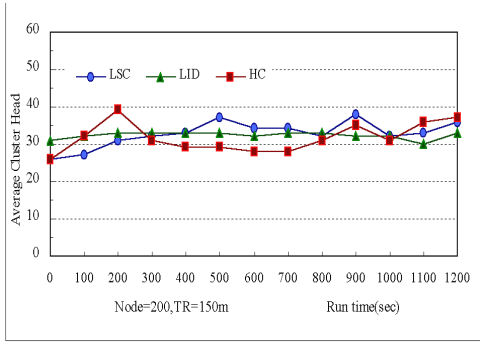


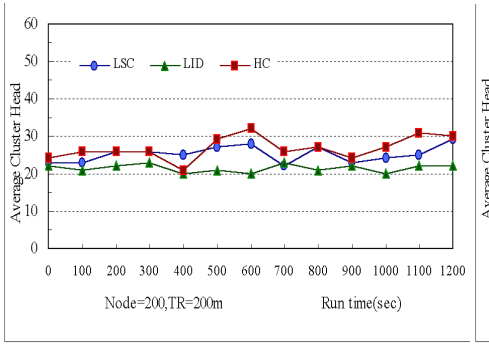


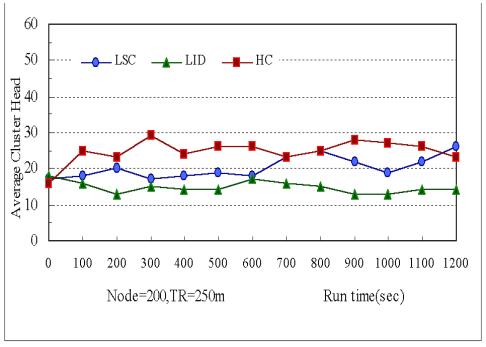












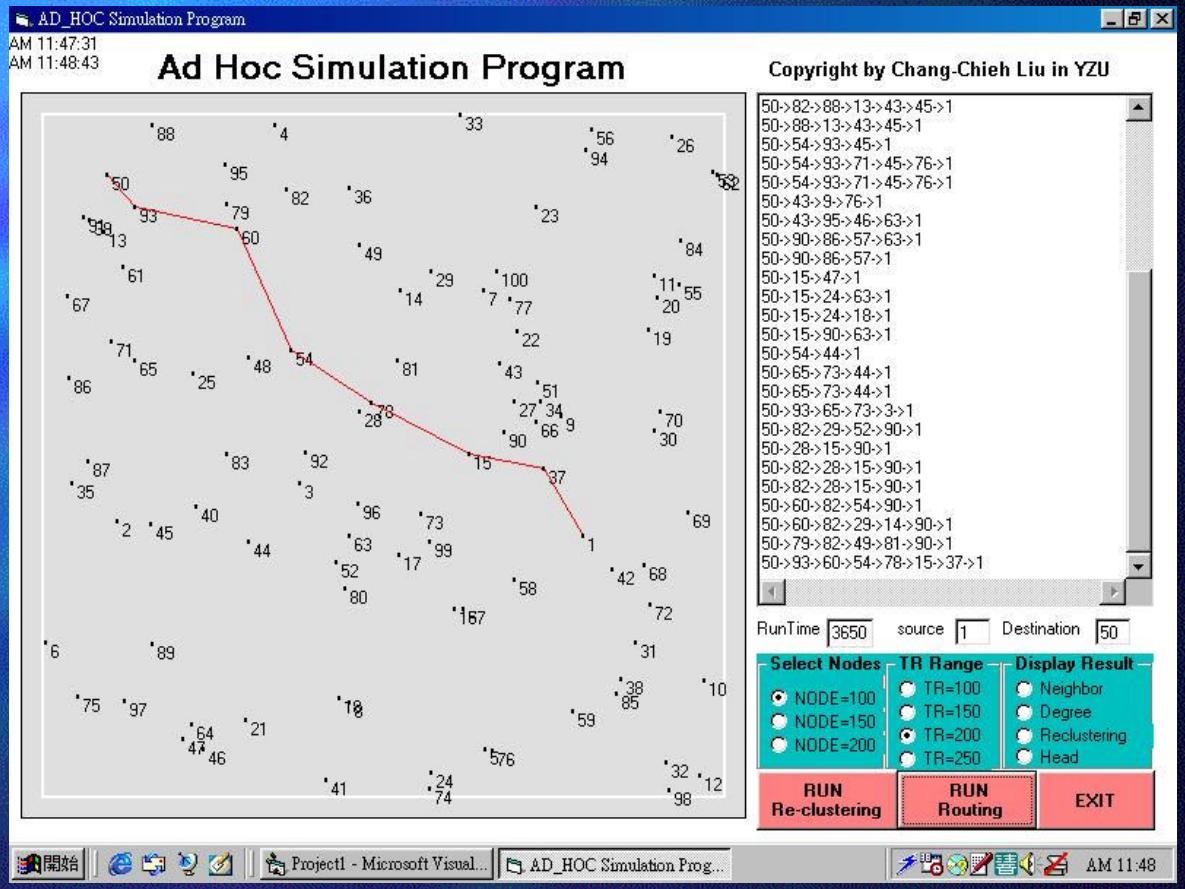
Simulation (cont.)

- **About re-clustering**
  - If transmission range of every hosts is larger. The probability of re-clustering becomes lower.
  - If transmission range of every hosts is the same, then the host has higher mobility the probability of re-clustering becomes higher.
  - In same transmission range of every host and if number of host in network is larger. The probability of re-clustering becomes higher.

Simulation (cont.)

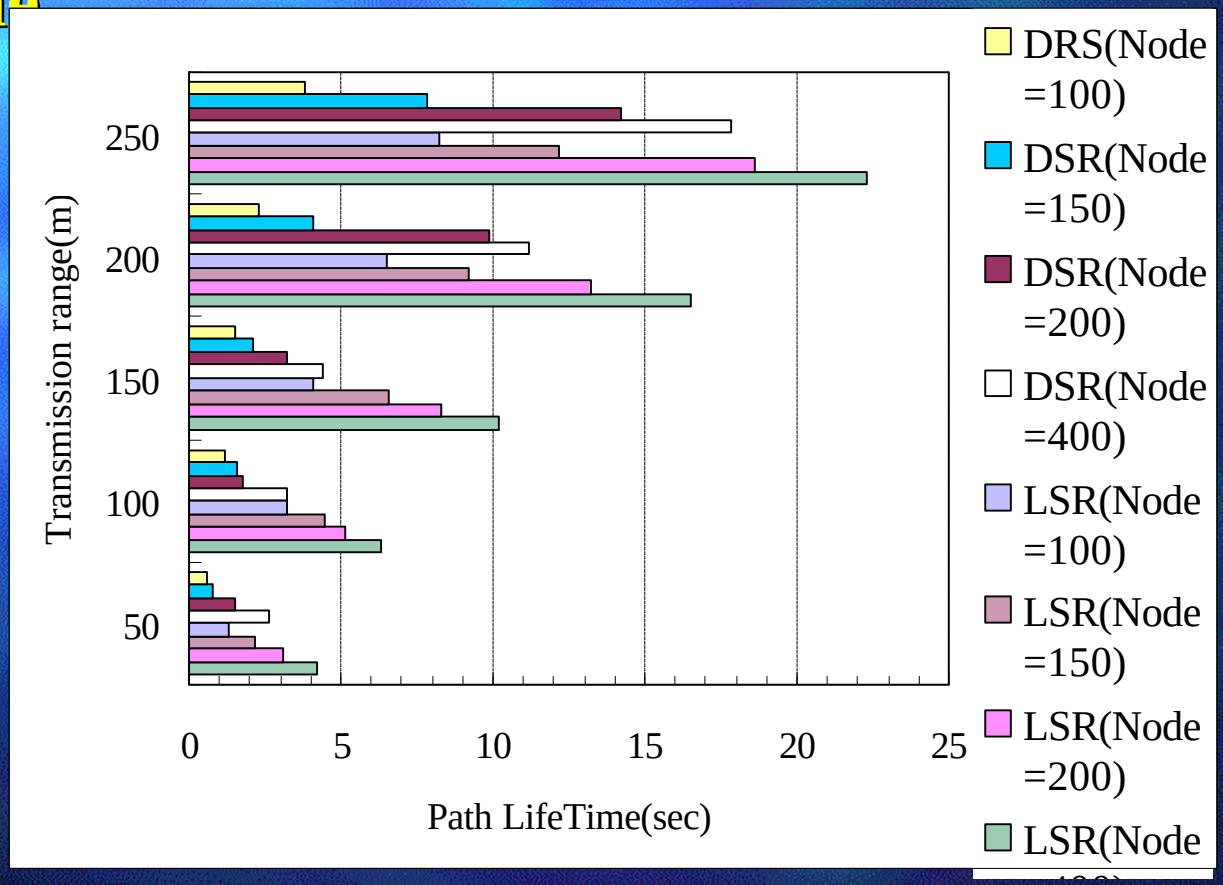
- **Start Routing simulation**

  Choice same network sizes with different transmission range . Found a path with different alg. Compare the path life time which broken during a time and less dropping probability.



Simulation (cont.)

- **Generate Graphics- Compared with path life time**

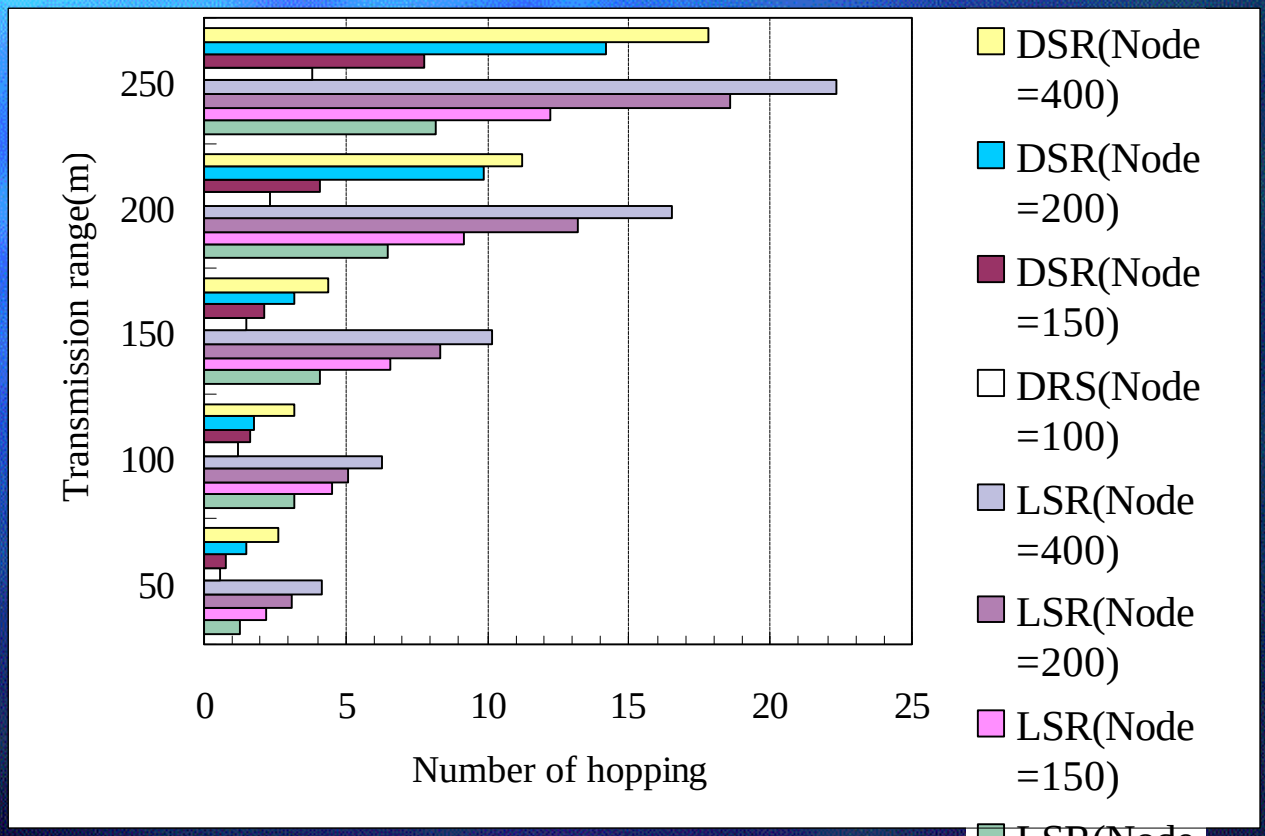


Simulation (cont.)

- **About path life time**
  - If number of host is same and transmission range of every hosts is larger. The path life time becomes longer.
  - If transmission range of every hosts is the same, then the host has higher mobility the path life time becomes shorter.
  - If same transmission range of every host and number of host in network is larger. The path life time becomes longer.

Simulation (cont.)

- **Generate Graphics- Compared with number of hopping**

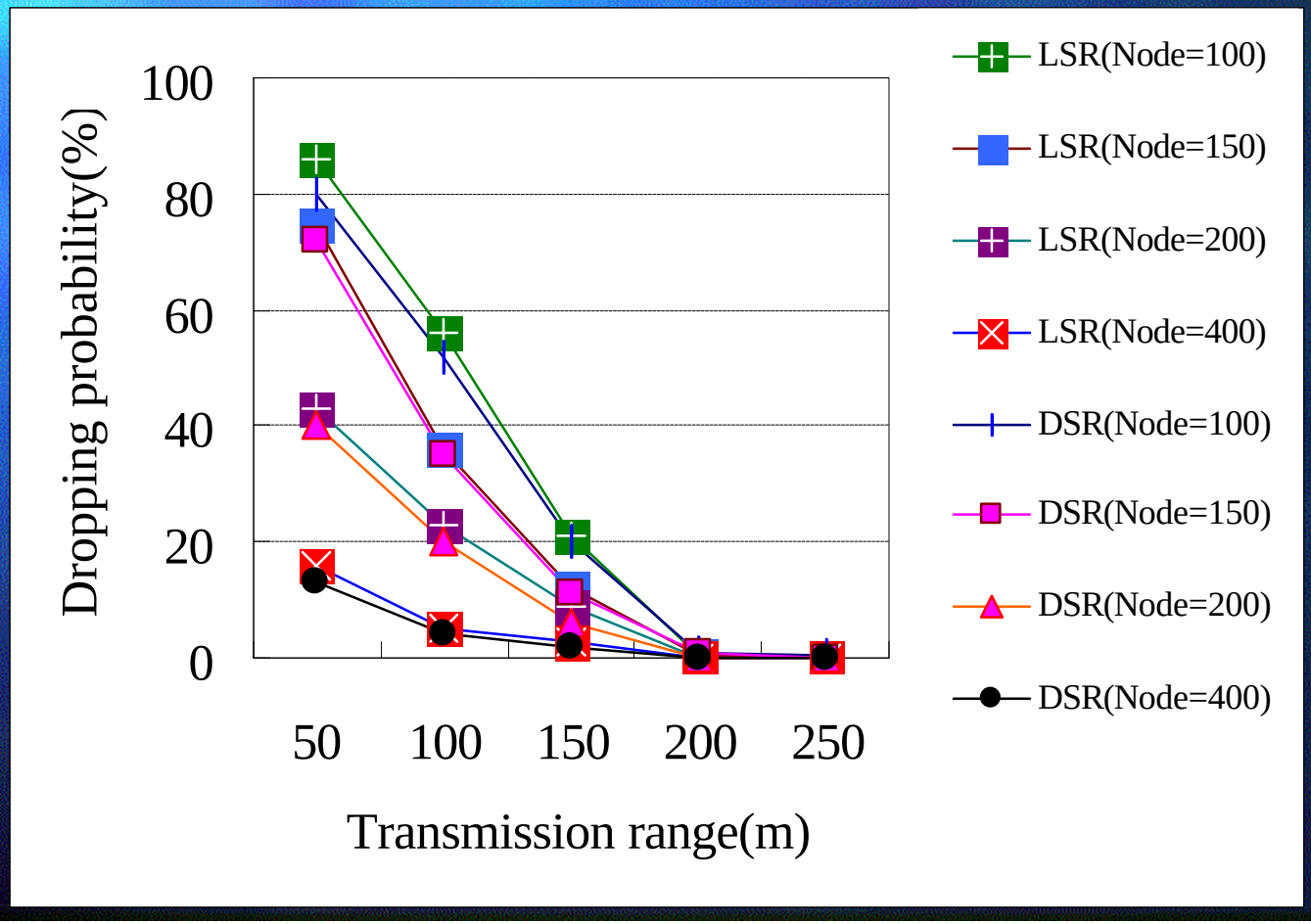


Simulation (cont.)

- **About number of hopping**
  - If number of host is same and transmission range of every hosts is larger. The number of hopping becomes smaller.
  - If same transmission range of every host and number of host in network is larger. The number of hopping becomes smaller.

Simulation (cont.)

- **Generate Graphics- Compared with dropping probability of RREQ.**



Simulation (cont.)

- **About dropping probability of RREQ**
  - If number of host is same and transmission range of every hosts is smaller. The dropping probability of RREQ becomes higher.
  - If same transmission range of every host and number of host in network is smaller. The dropping probability of RREQ becomes higher.
  - If transmission range of every hosts is smaller and the host in network is smaller. The dropping probability of RREQ becomes very high.

Conclusion

- **Clustering simulation**
  - **In those figures, the result can proved that using the LSC alg. had less probability of re-clustering in networks and it had great stability of clusters than the HC and LID .**
  - **Although the LSC alg. increase little bits of weak and medium links data in packet than the HC and LID alg., but LSC had great stability of clusters. It didn't non-necessary re-clustering caused. So, the overhead always less than the HC and LID.**
  - **Same condition, the average cluster created of those clustering algorithms during simulation is no more difference. So, not necessary to compare with average re-clustering of every cluster.**

Conclusion (cont.)

- **Routing simulation**
  - In those figures, the result can proved that using LSR alg. It had longer path life time, less probability of path broken and dropping probability of RREQ. So, the LSR had great stability of path than the DSR.
  - In those figures, we found that using LSR alg. to compare with DSR not had more than two or three hopping of path. Although the LSR alg. increase less hop of path than DSR alg. , but LSR had great stability of path. It's not often to route discovery when path broken. So, the overhead always less than the DSR.