Capturing User Friendship in WLAN Traces

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Motivation

- **Intuitively, sub-groups of people on university campuses show closer relationship.**
  - **How is such "relationship" reflected in the WLAN traces?**
  - **How to define metrics for such behavior?**
  - **What are the inferences of these sub-groups of friends on network structures?**
- **We use WLAN from 4 different sources to understand grouping behavior realistically.**

Wireless LAN traces used

Trace source	Unique users	Unique APs	Unique buildings	Trace duration	User type	Environment	Trace collection method	Analyzed part in this paper	Users in analyzed part	Labels used in graphs
MIT[1]	1,366	173	3	Jul. 20 '02 to Aug. 17 '02	Generic	3 Engineer buildings	Polling	Whole trace	1,366	MIT-cons MIT-rel
Dartmouth[3]	10,296	623	188	Apr. '01 to Jun. '04	Generic	Whole campus	Event-based	Jul. 2003	2,518	Dart-03
								Mar. 2004	5,416	Dart-04 Dart-rel Dart-cons
UCSD[2]	275	518	N/A	Sep. 22 '02 to Dec. 8 '02	PDA only	Whole campus	Polling	Sep. 22 '02 to Oct. 21 '02	275	UCSD
USC	4,548	79 ports	73	Dec 03-Now (trap) Apr 20 05-Now (detail)	Generic	Whole campus	Event-based	Apr. 20, '05 to May. 19 '05	4,528	USC

- **Traces from environments with various settings.**
- **In each trace we have AP association history of individual nodes.**
- **Objective: Capture "close relationship" between nodes.**

Friendship Index

- **Intuitively, if two nodes appear together "more often", it indicates closer relationship between them.**
- **Define friendship index based on two metrics:**
  - **Encounter time between the node pair**

$$Frd_t(A,B) = E_t(A,B) / Online\_time(A)$$

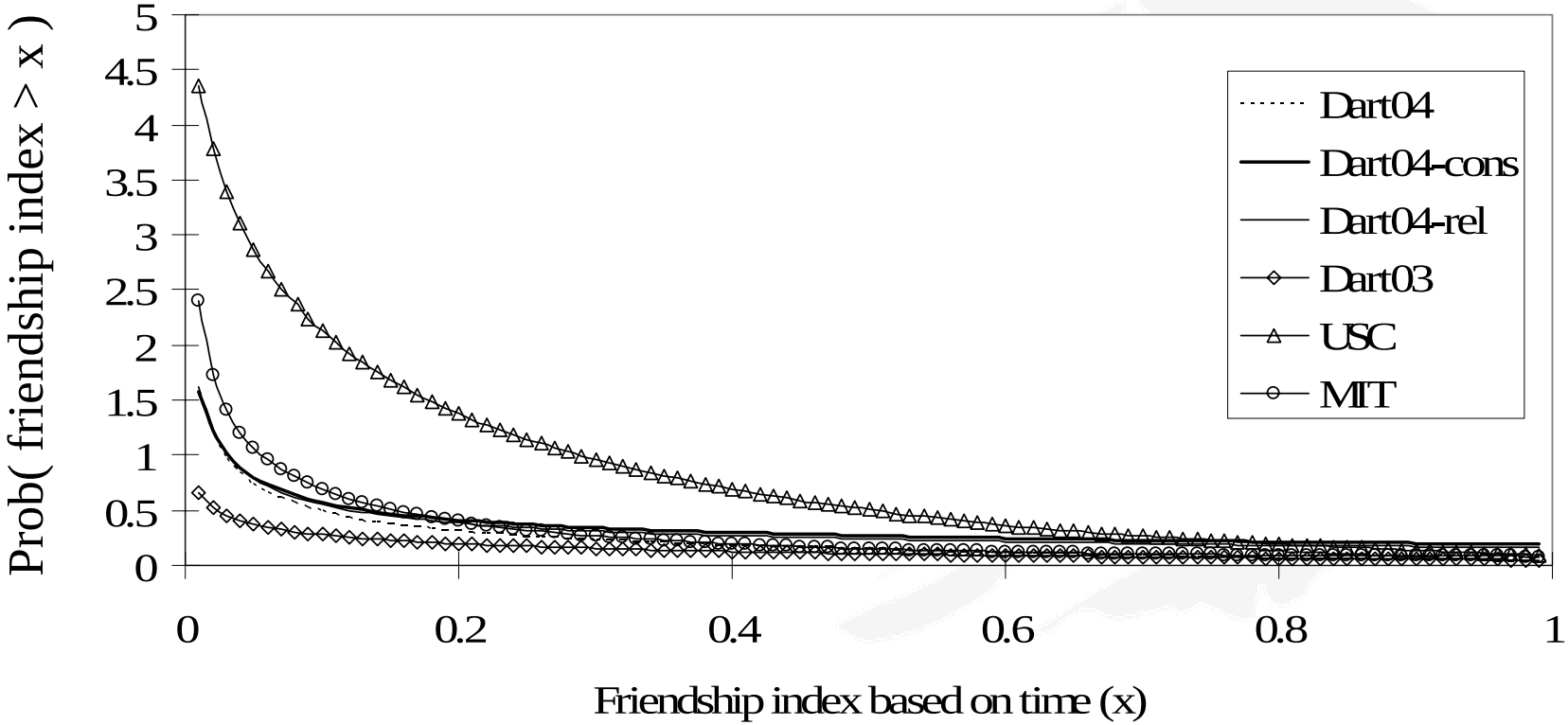
  - **Encounter count between the node pair**

$$Frd_c(A,B) = E_c(A,B) / Session(A)$$

Et(A,B): Total encounter duration between node A, B.
Ec(A,B): Encounter count between A,B
Online_time(A): Total online duration for node A
Session(A): Total number of sessions for node A

Friendship Index

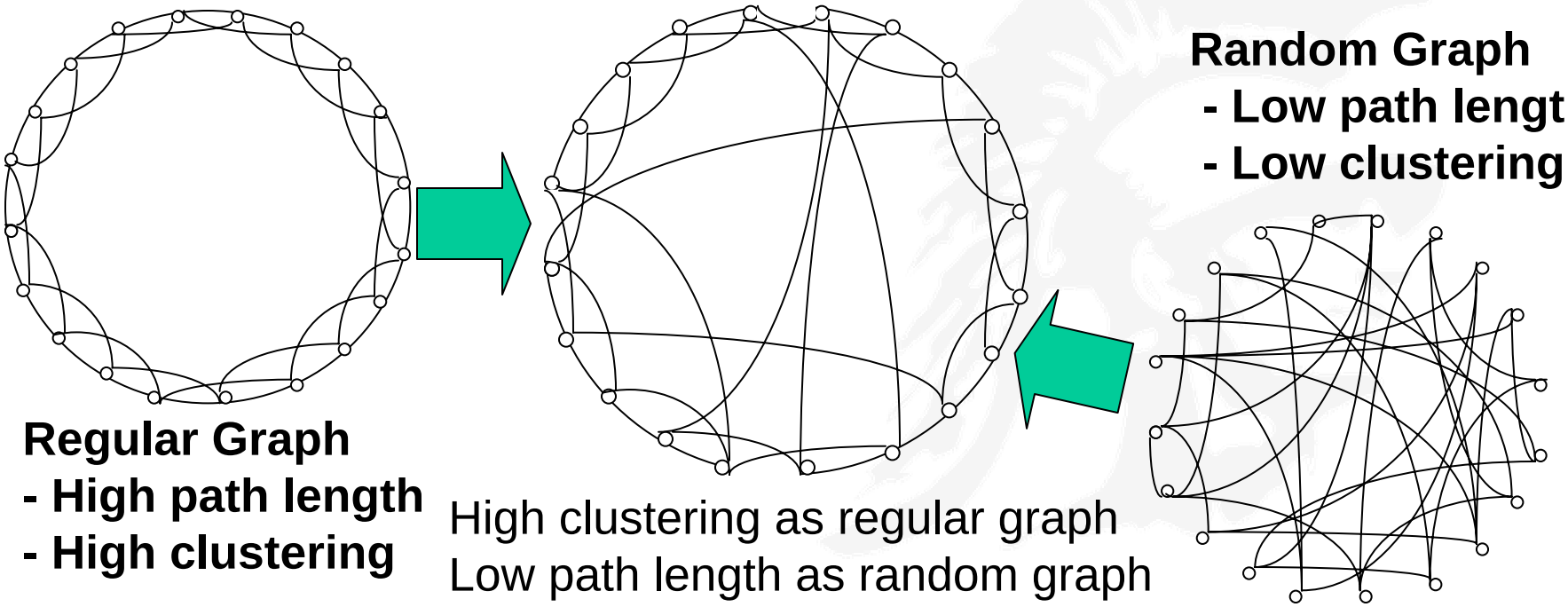
- **Friendship is very skewed: Few pairs of nodes have high friendship index (Exponential dist.)**



Encounter-Relationship Graph

- **Put a link to connect the node pairs if they ever encounter with each other… What does the graph look like?**

SmallWorld graph



Random Graph
- Low path length
- Low clustering

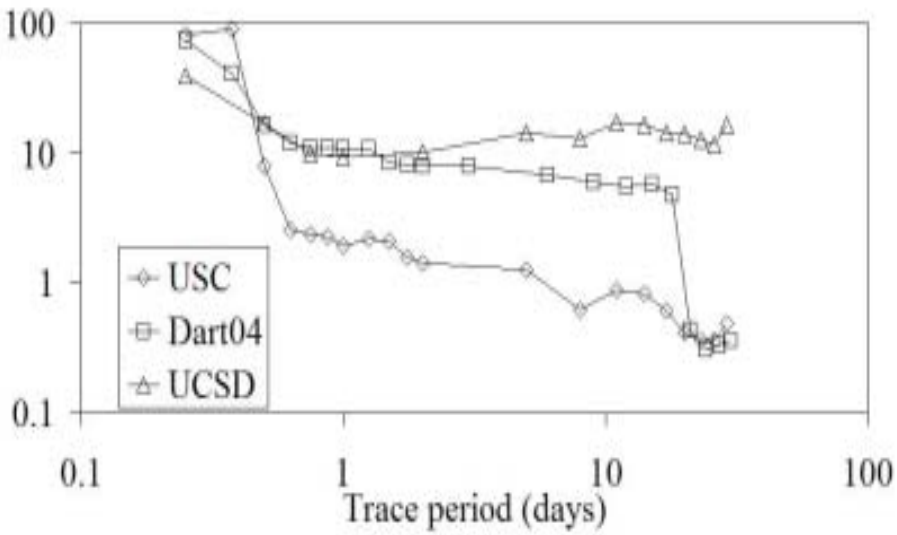
Regular Graph
- High path length
- High clustering

High clustering as regular graph
Low path length as random graph

Encounter-Relationship Graph

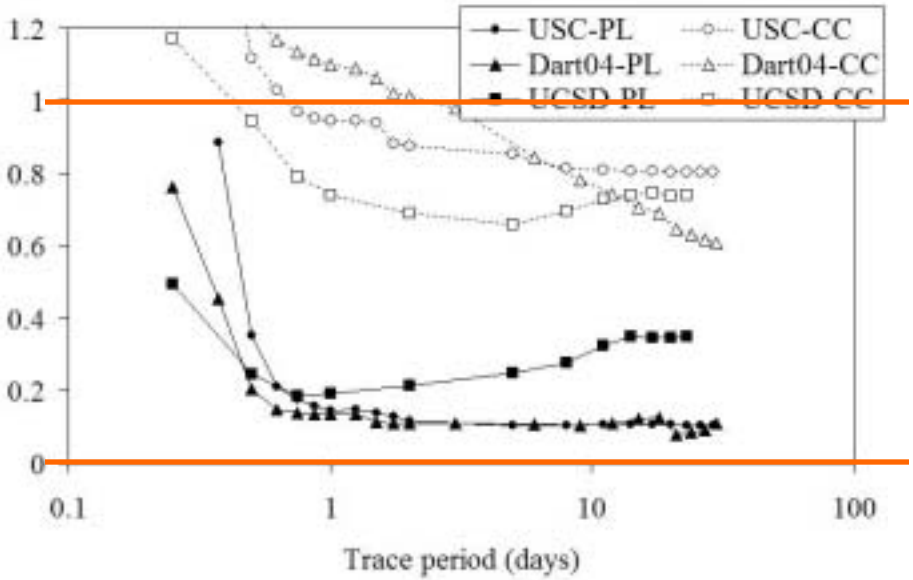
- **It is a connected graph**

Disconnected ratio drops to below 10% for trace duration longer than 1 day.



- **It is a SmallWorld graph**

Normalized clustering coef. (CC) close to regular graph and average Path Length (PL) close to random graph



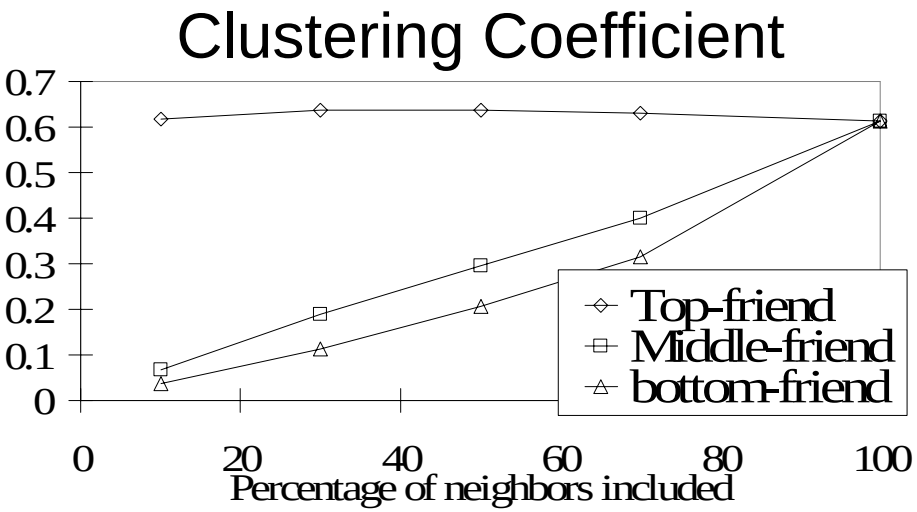
Normalized PL/CC: 1 corresponds to regular graphs, 0 corresponds to random graphs

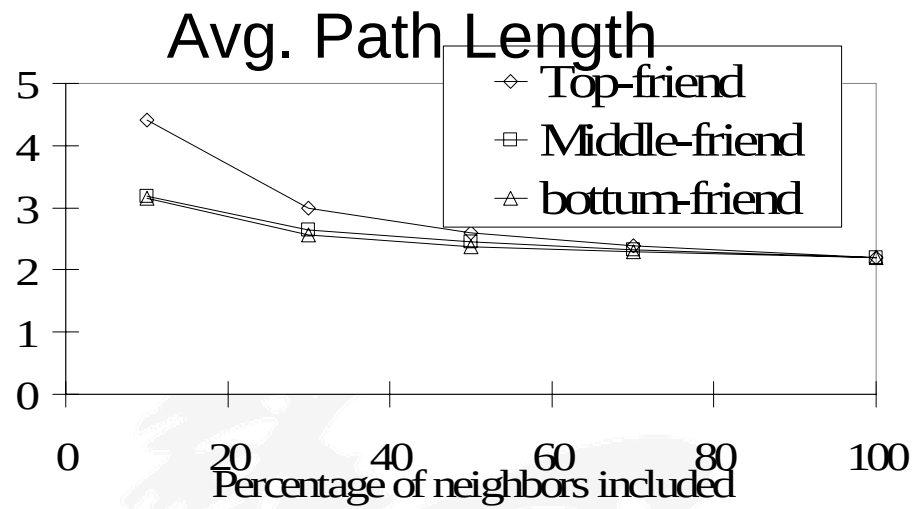
ER Graph with Friends

- **Sort the encountered nodes according to friendship indexes for each node, and include only part of them in the ER graph. How does it change the graph property?**
  - **Higher tendency of clustering if only top-friends are included.**
  - **Higher average path length and disconnected ratio if only top-friends are included.**
  - **The above observations are consistent regardless of which definition of friendship index is chosen.**

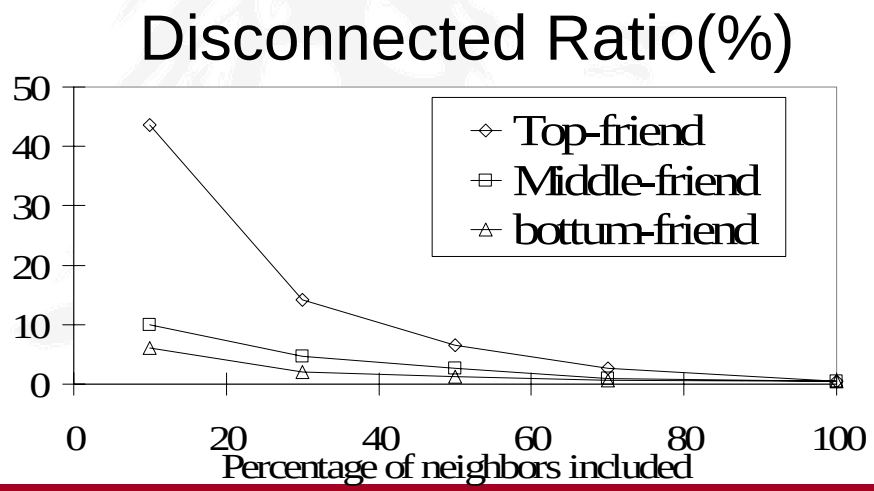
ER Graph with Friends

- **Using friendship index based on *encounter time***



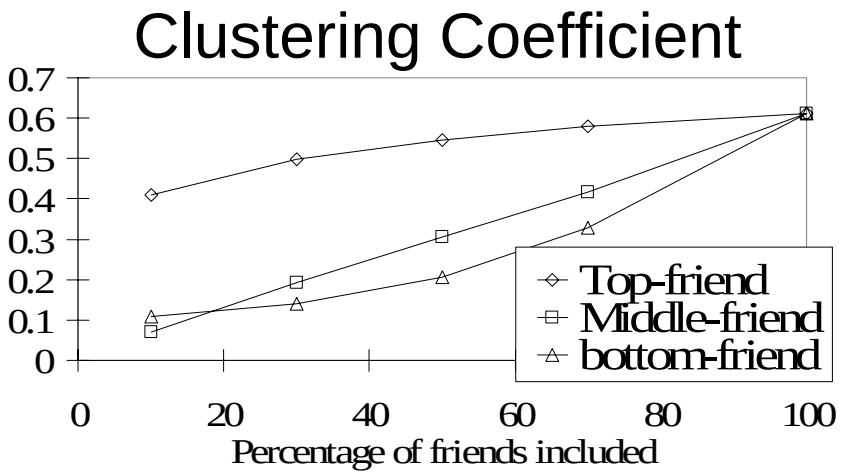


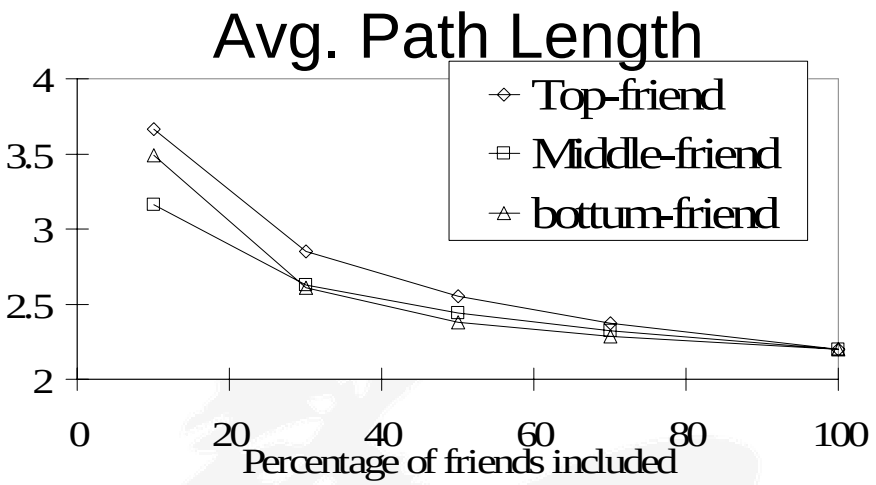
- Using high-ranked friends only in the ER graph leads to graph properties closer to regular graphs. Using low-ranked friends leads to graph properties closer to random graphs.



ER Graph with Friends

- **Using friendship index based on *encounter count***





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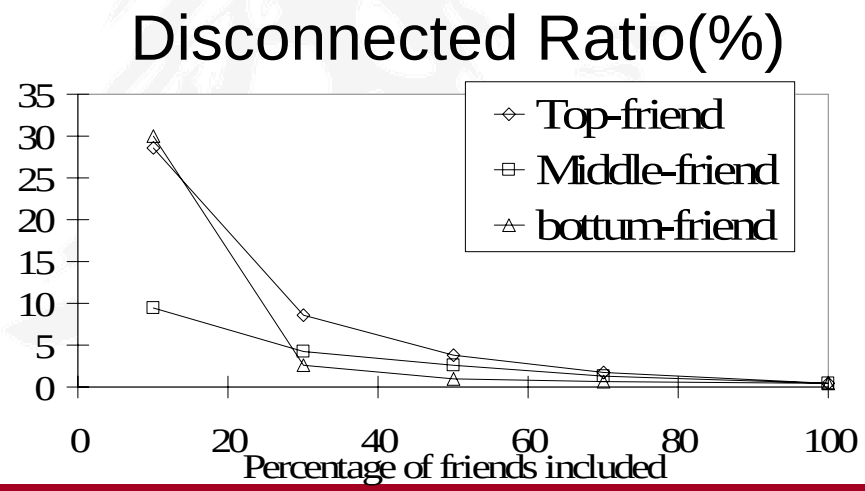

Conclusion

- **Friendship between nodes in WLAN traces defined based encounter time or encounter count.**
- **Friendship is skewed: Few node pairs with high friendship index, many with low friendship index.**
- **Encounters link nodes into connected SmallWorld graphs.**
- **Including nodes with high friendship indexes make the encounter-relationship graphs shift toward regular graphs.**

Implication

- **While people tend to trust others with close relationship, random links may be the key to maintain a connected network.**

References

- W. Hsu and A. Helmy, “On Nodal Encounter Patterns in Wireless LAN Traces," the Second International Workshop On Wireless Network Measurement (WiNMee 2006), April 2006.
- [1] M. Balazinska and P. Castro, “"Characterizing Mobility and Network Usage in a Corporate Wireless Local-Area Network," In Proceedings of MobiSys 2003, pp. 303-316, May 2003.
- [2] M. McNett and G. Voelker, “"Access and mobility of wireless PDA users,”" ACM SIGMOBILE Mobile Computing and Communications Review, v.7 n.4, October 2003.
- [3] T. Henderson, D. Kotz and I. Abyzov, “"The Changing Usage of a Mature Campus-wide Wireless Network,”" in Proceedings of ACM MobiCom 2004, September 2004.