UNIVERSITY OF CAMBRIDGE
Computer Laboratory

Haggle

Evolution of Networking Research in Haggle: from pure forwarding to social networking (through data dissemination)

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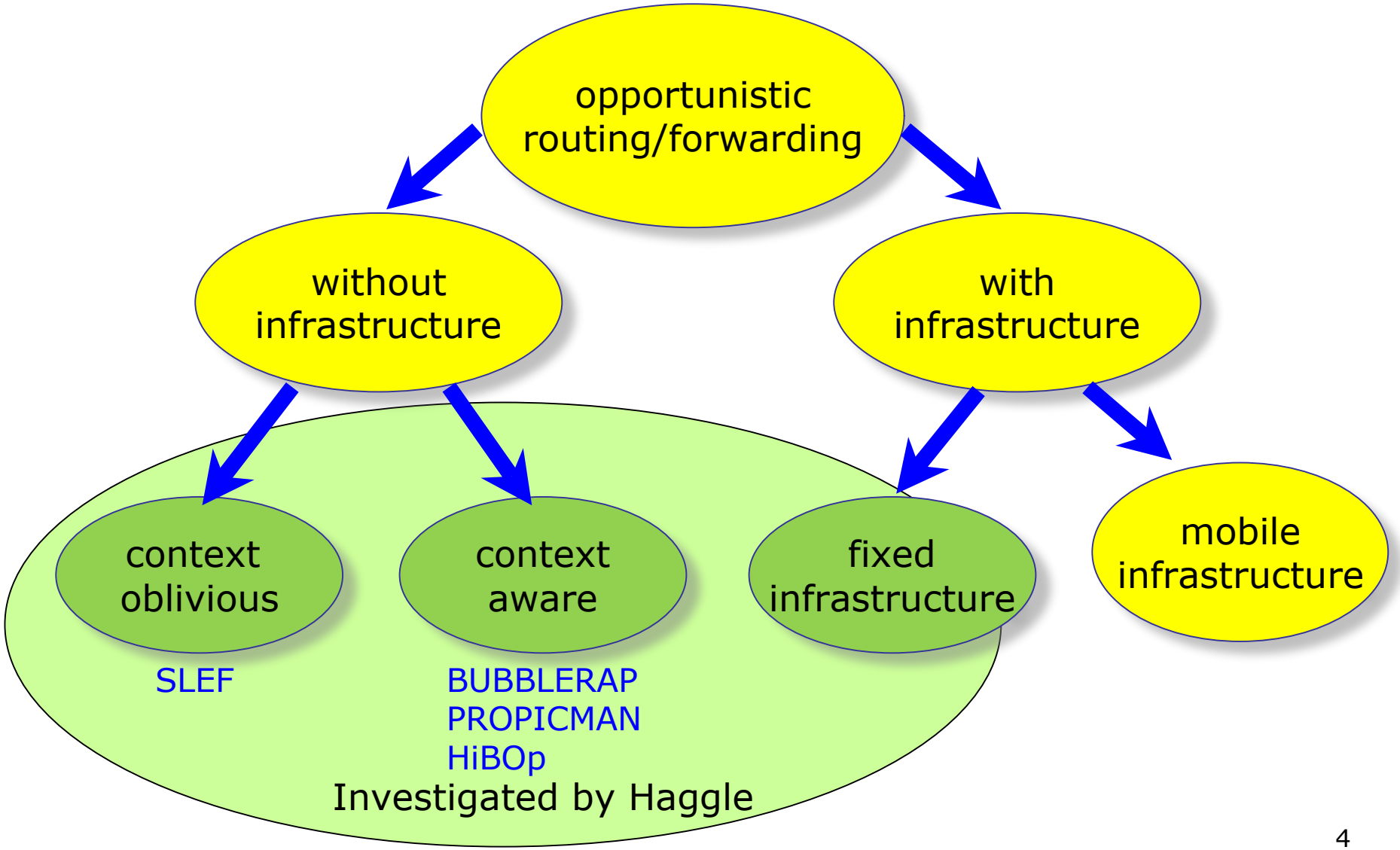
Outline

- Looking back of data communication in Haggle
- Forwarding
- Forwarding to content dissemination
- Emergence of social networking
- Conclusion

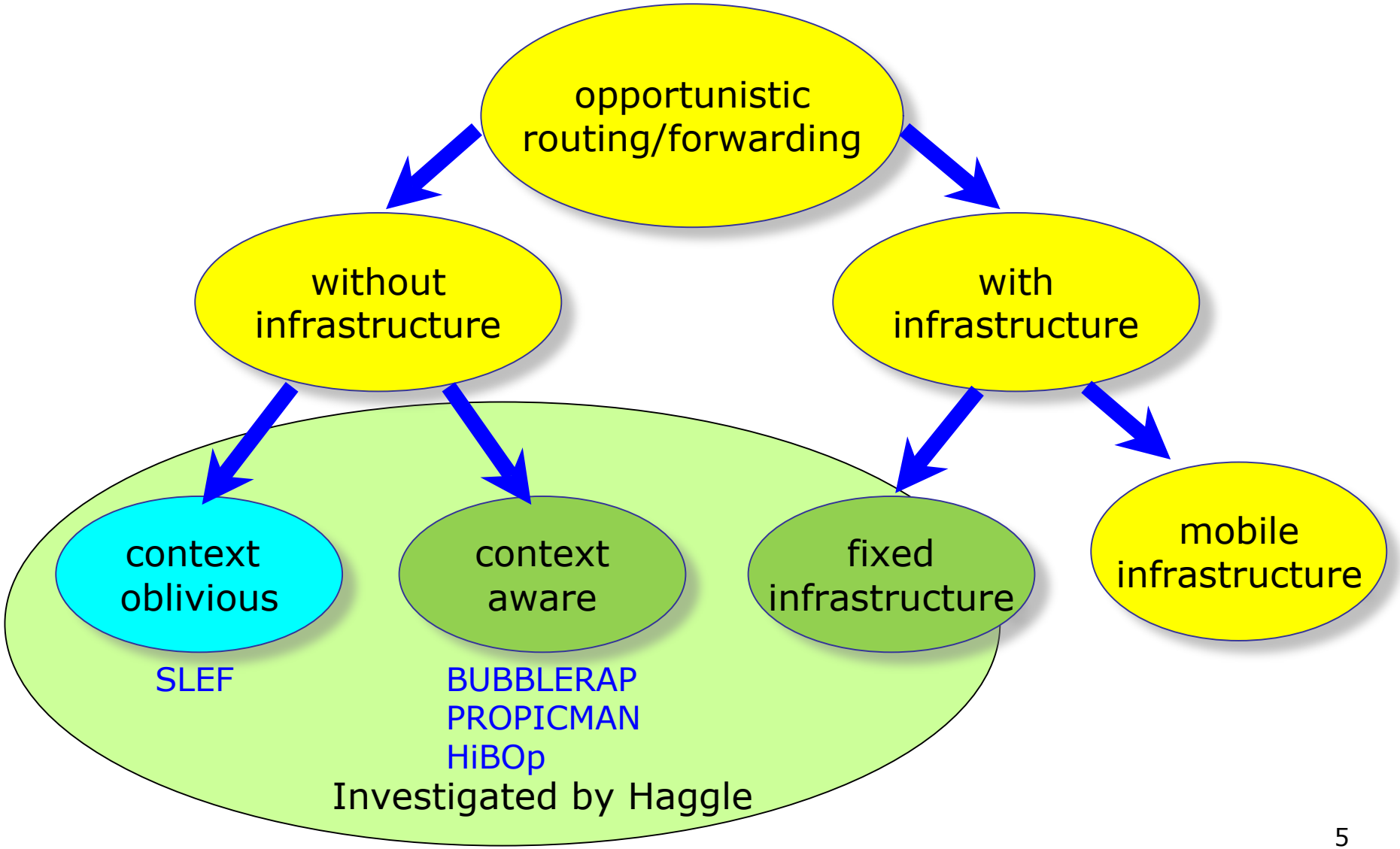
Looking Back

- First (2006), forwarding in opportunistic networks
  - Because this was the really compelling problem
  - Several alternatives investigated
- Focus moved to data dissemination
  - Because opportunistic networks are expected to be content centric
  - ContentPlace, Socio-Aware Overlay, search-based Haggle architecture
- Lessons learned
  - Opportunistic networks are *human*
  - Social networking is a must (cross layering)
  - Social networking is an opportunity (applications, e.g. Opportunistic Twitter, MobiClique)

Forwarding in Haggle

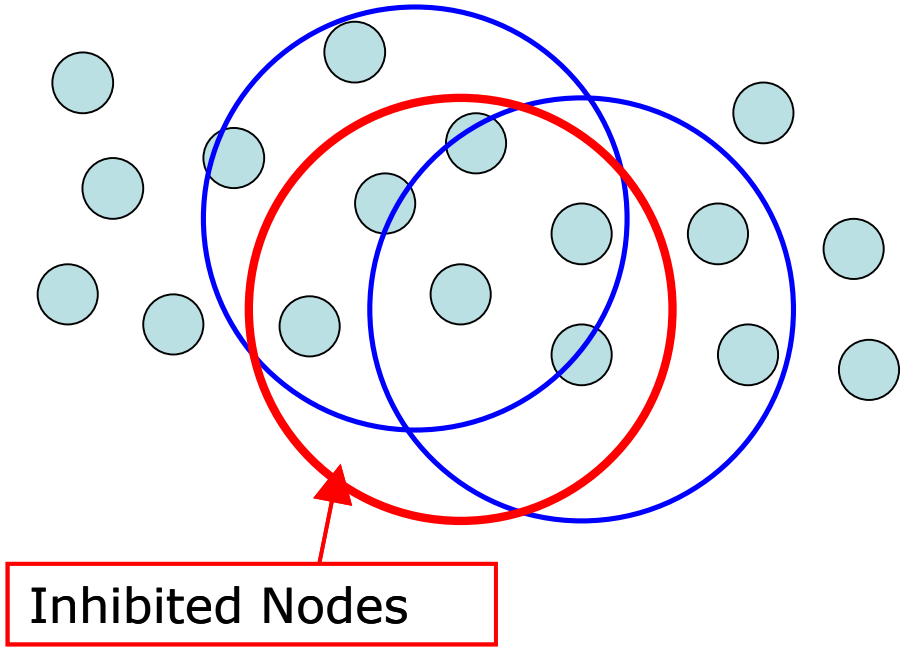


Forwarding in Haggle



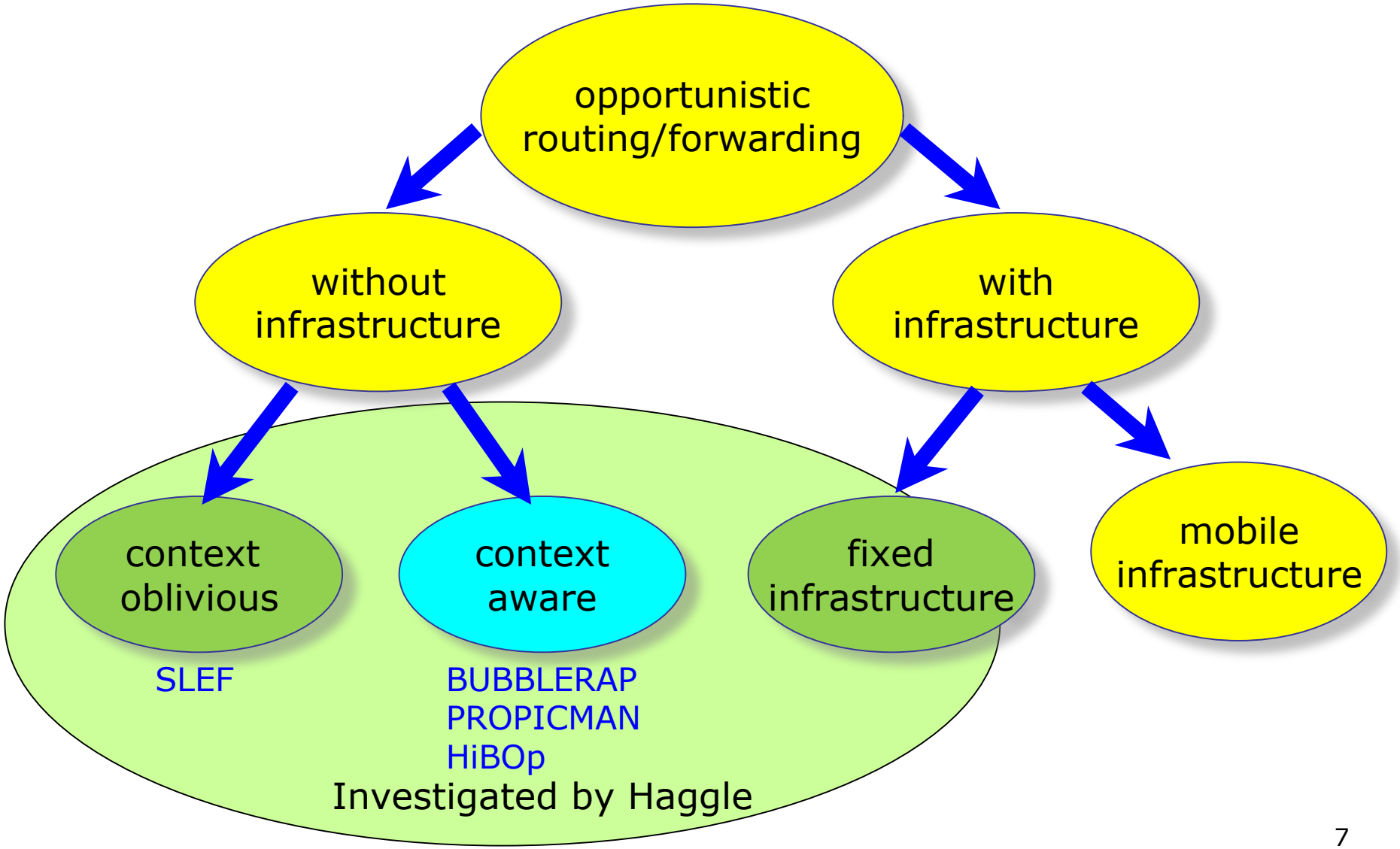
SLEF: Self Limiting Epidemic Forwarding (EPFL)

- SLEF is an optimized version of multi-hop broadcast
  - Nodes forward each packet they receive with a given probability: *Forwarding Factor (FF)*
  - Inhibition: FF of a packet decreases with every send/receive
  - Buffer management: Clean buffer for new incoming packets



- SLEF addresses:
  - Congestion control
  - Efficient use of MAC broadcast
  - Schedule/fairness
- SLEF uses only local information

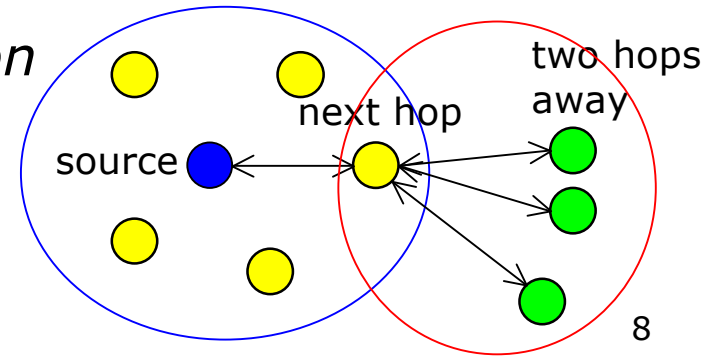
Forwarding in Haggle



PROPICMAN (SUPSI)

- Probabilistic Routing Protocol for Intermittently Connected Mobile Ad hoc Networks
- Fully context-aware protocol
  - Exploit the context information of nodes to select the best next-hop candidate (e.g. work place, city, street, hobby)
  - Each node has a common Node Profile with evidence/value pairs, evidences have different weights
  - Source sends destination's profile to neighbours a message header (concatenation of hash of evidence/value pair)
  - Neighbor(s) do local matching between received header and node profile, and compute delivery probabilities

Two-hop routing probability selection



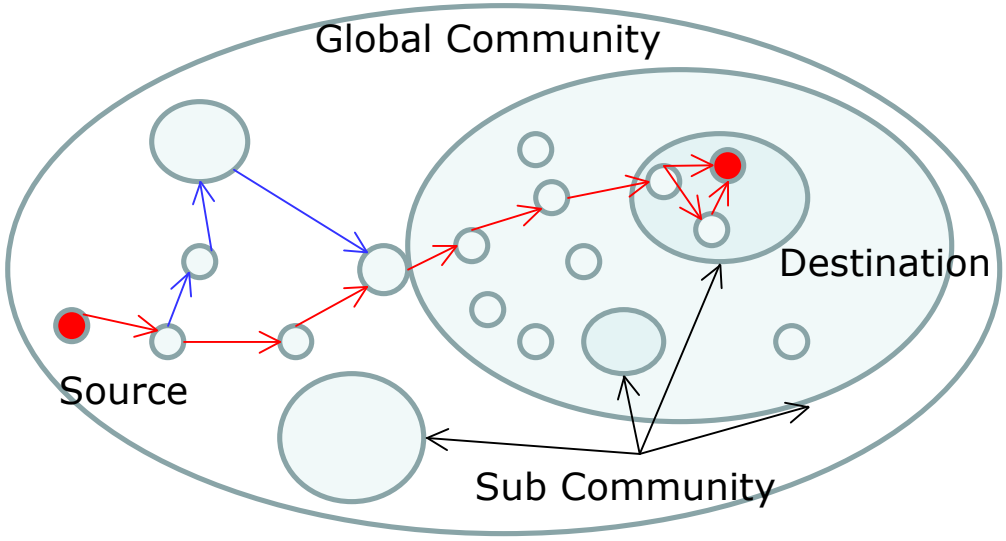
- HiBOp (CNR): Similar approach

BUBBLE RAP Forwarding (CAMCL)

- Optimisation of Epidemic Forwarding
  - Epidemic forwarding - highly robust against disconnection, mobility, and node failures; simple, decentralised, and fast
  - Control Flooding is necessary (e.g. Location, Count-base, Timer, History)
- Use of Social Structure for Communication
- Social hubs (e.g. celebrities and postman) as betweenness centrality and combining community structure for improved routing efficiency

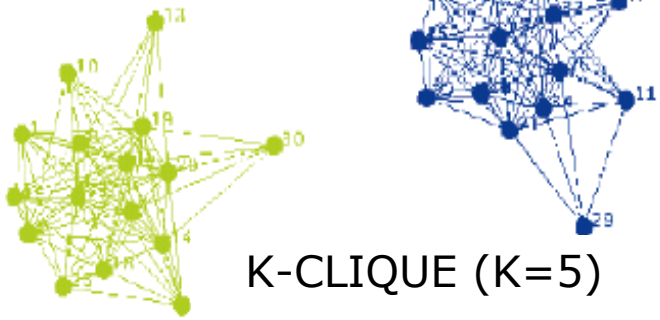
BUBBLE RAP Forwarding (CAMCL) cont.

- RANK Centrality based: Global and Local ranking of popularity
- LABEL Community based
- BUBBLE RAP Combination of centrality and community

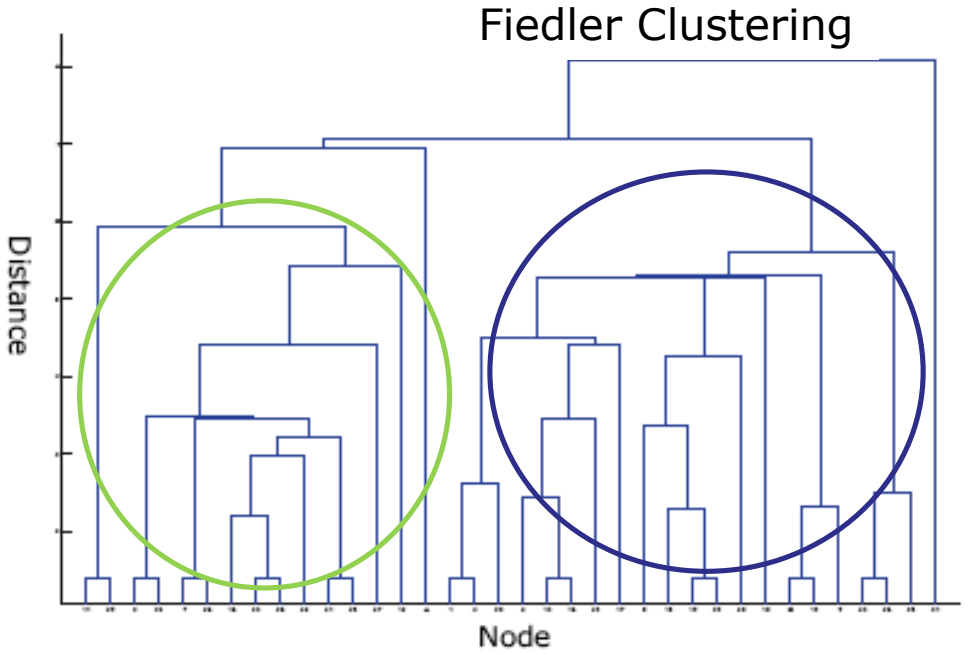


Uncovering Community

- Contact trace in form of weighted (multi) graphs
  - Contact frequency and duration
- Use community detection algorithms from complex network studies
  - K-clique, Weighted network analysis, Betweenness, Modularity, Fiedler Clustering etc.

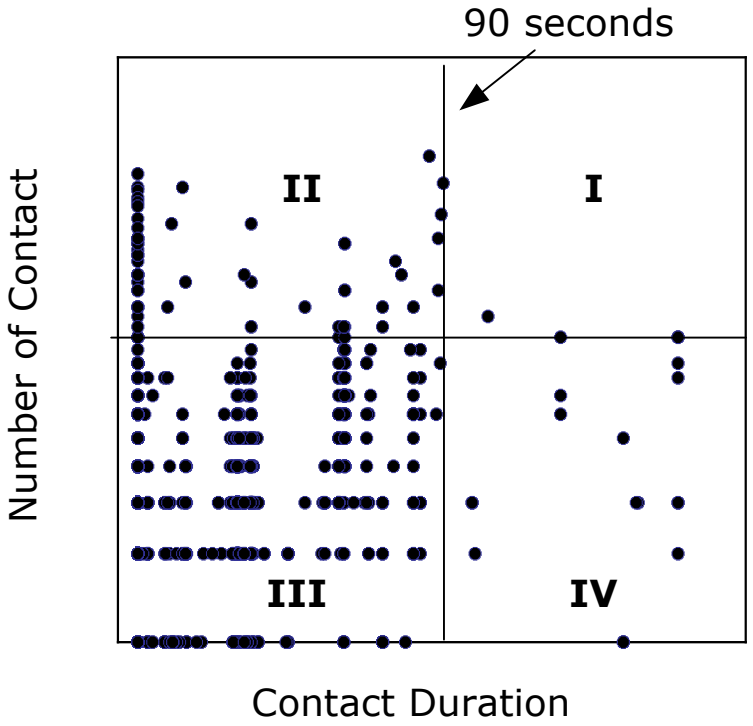


K-CLIQUE (K=5)



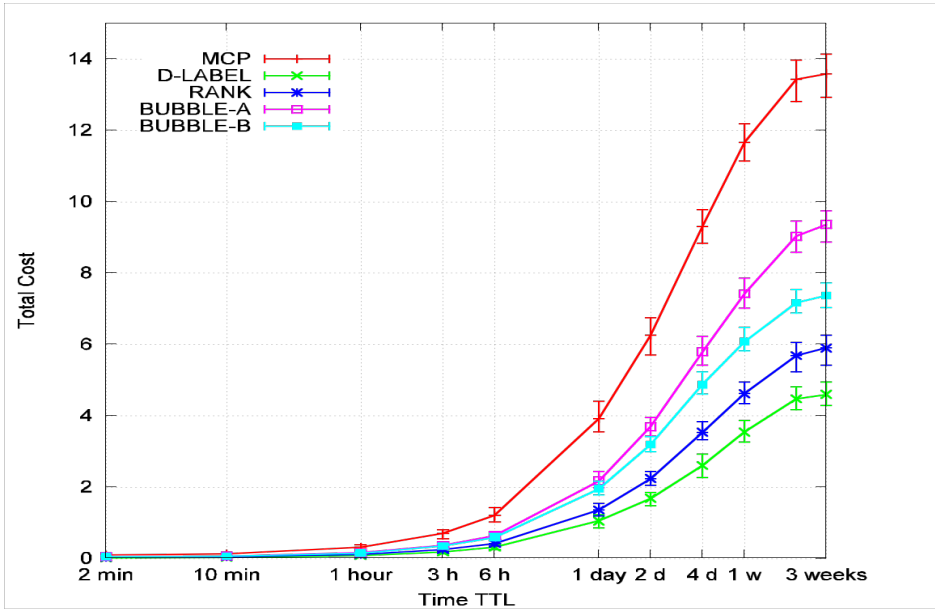
Edge Weight→ Community Detection

I. High Contact Nº - Long Duration: Community
II. High Contact Nº - Short Duration: Familiar Stranger
III. Low Contact Nº - Short Duration: Stranger
IV. Low Contact Nº - Long Duration: Friend



BUBBLE : Performance

- Performance: Significant cost reduction



- Comparison of delivery ratio (left) and cost (right) of MCP(multiple-copy-multiple-hop - 4 copies and 4 hops case) and RANK

Forwarding to Content Dissemination

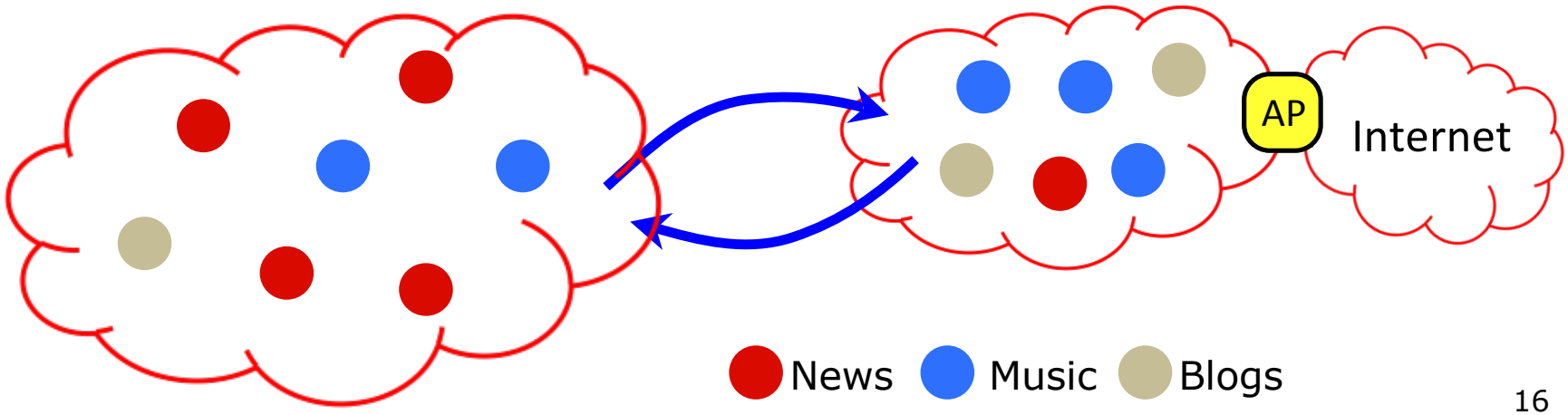
- Emergence of User Generated Content already in the static Internet
- Opportunistic networks will be a multiplier for this
  - user generating and sharing content anywhere anytime
- Driven by contents
  - key issues: efficient content management & dissemination
- Shift from plain forwarding of messages to intelligent dissemination of content
  - *Content-Centric Networking* (Uppsala)
  - *ContentPlace* (CNR)
  - *Socio-aware overlay for publish/subscribe (CAMCL)*

Content Centric Haggle (Uppsala)

- Build graphs of interests through encounters and disseminate accordingly
- Resolution – the search aspect of Haggle
  - Find **target nodes** in relation graph matching a data object, or vice versa
  - Data objects (and nodes) are ranked
- Interest forwarding
  - Give data object to neighbor with matching interests
- Delegate forwarding
  - Delegate data object to neighbor with higher forwarding metric but no interest in the data object (e.g. BUBBLE-RANK)

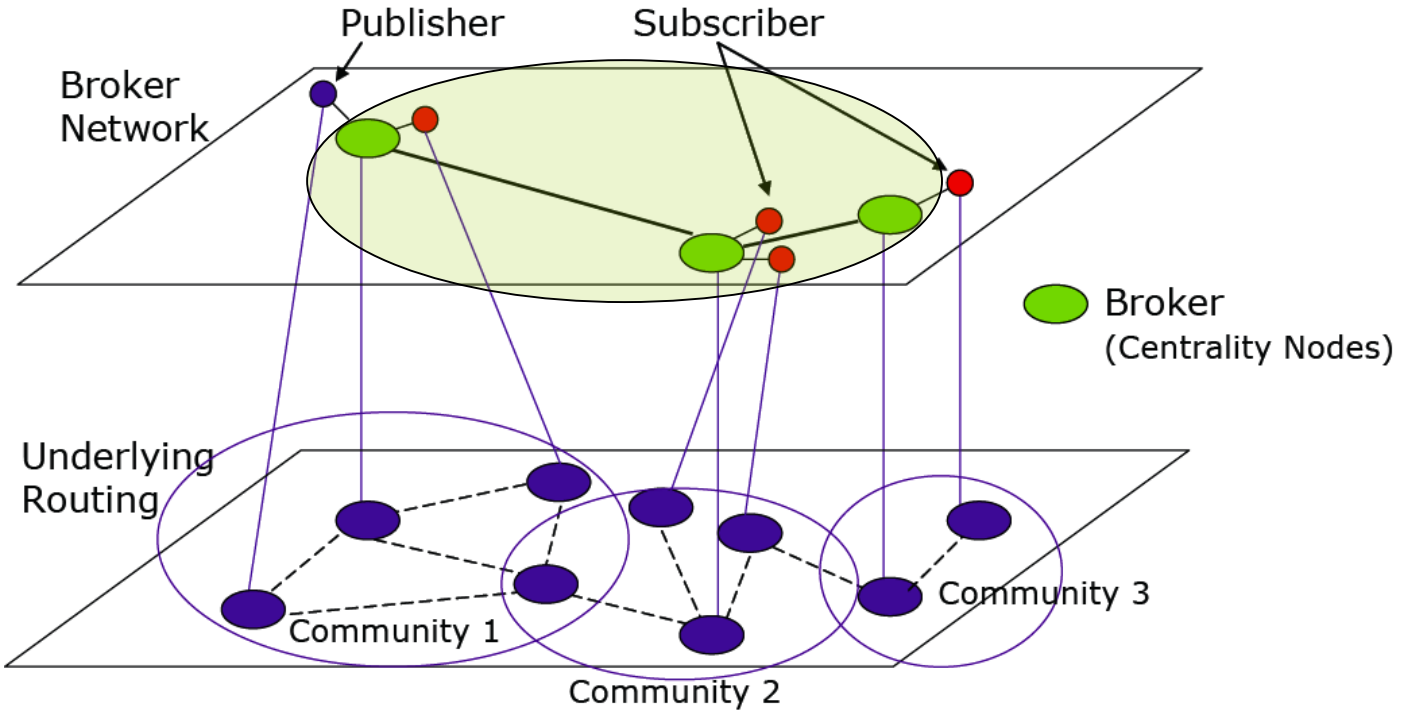
Content Place (CNR)

- Dissemination based on social relationships and interests
  - Multi-community: Different distribution of interests in different communities
  - Social-oriented knowledge (each user)
    - which communities the user is usually in touch with
    - what users are interested into (within each community)
- Policy for content placement: Social and non-social content



Socio-Aware Overlay (CAMCL)

- Overlay over Communities for Publish/Subscribe
- Subscription Propagation during Community Detection
  - Closeness Centrality Nodes Creates Overlay
  - Closeness Centrality ~= 1.0
  - Multiple Centrality Nodes Coexist → Resource/Load Sharing

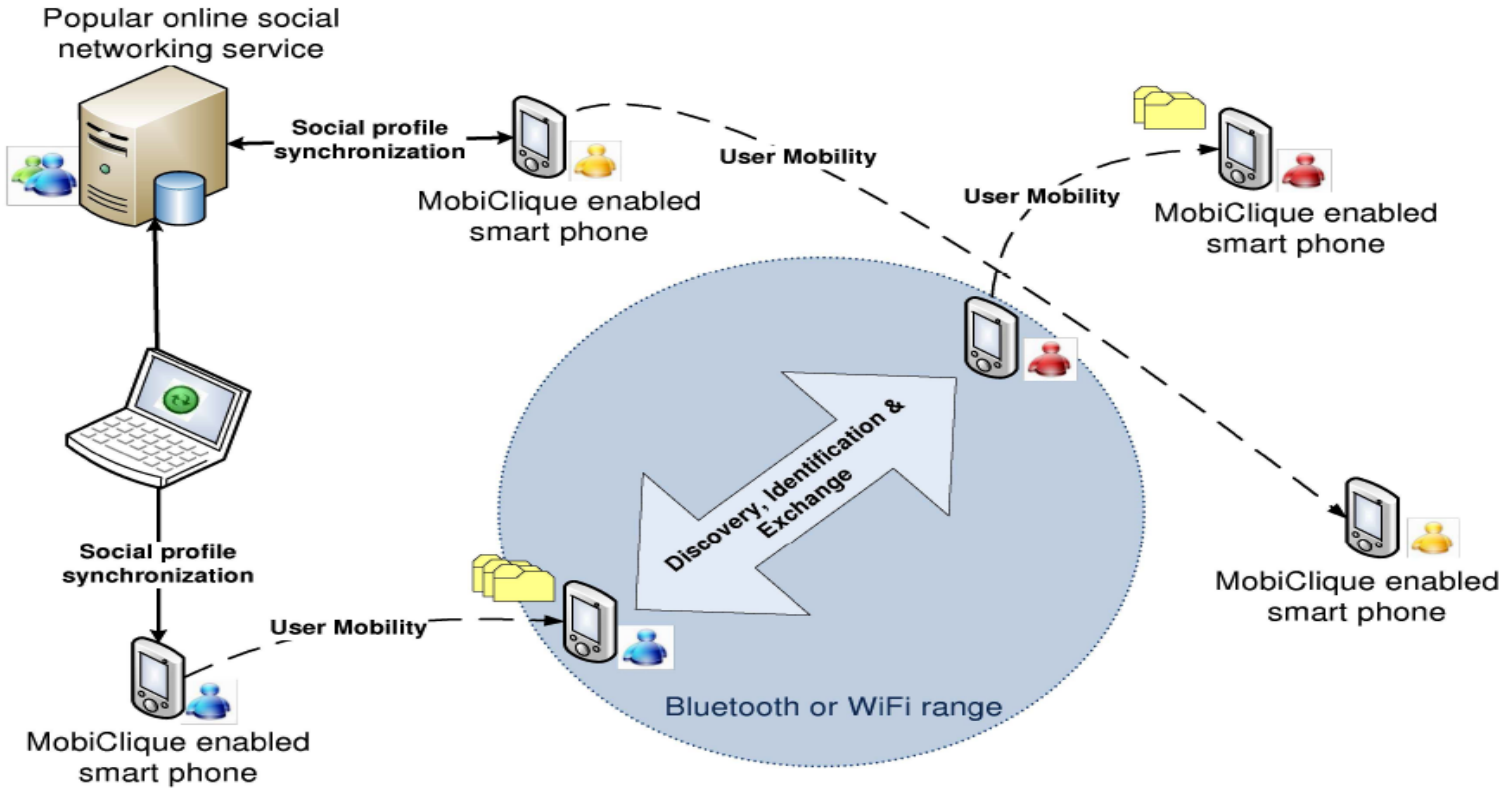


Emergence of Social Networking

- Opportunistic networks are Human in nature
  - Devices carried by people, thus 'do what users do'
  - Mobile devices are used for gathering and sharing user generated content
- Links to social networking
  - Information about social relationships to be used as contextual information to optimise protocols
    - e.g. HiBOp, PROPICMAN, ContentPlace
  - Use human social network structure (e.g. community)
    - e.g. BUBBLERAP
  - Mobile social networking applications
    - Situation awareness intrinsic in opportunistic networks as an added value
    - e.g. MobiClique, Opportunistic Twitter

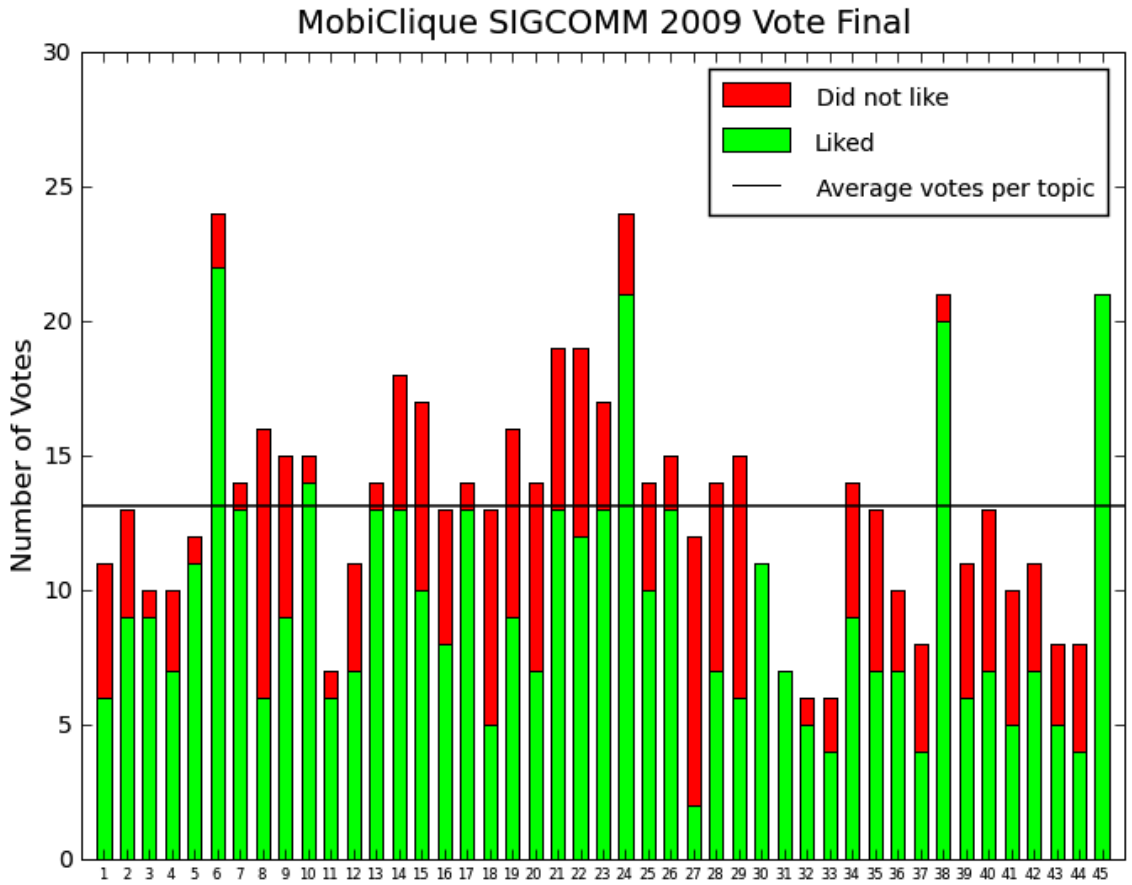
MobiClique (Technicolor)

- Mobile social networking software: to manage users' social network on their mobile device and to exchange messages with friends and communities of users sharing similar interests
- Store-carry-forward without any infrastructure



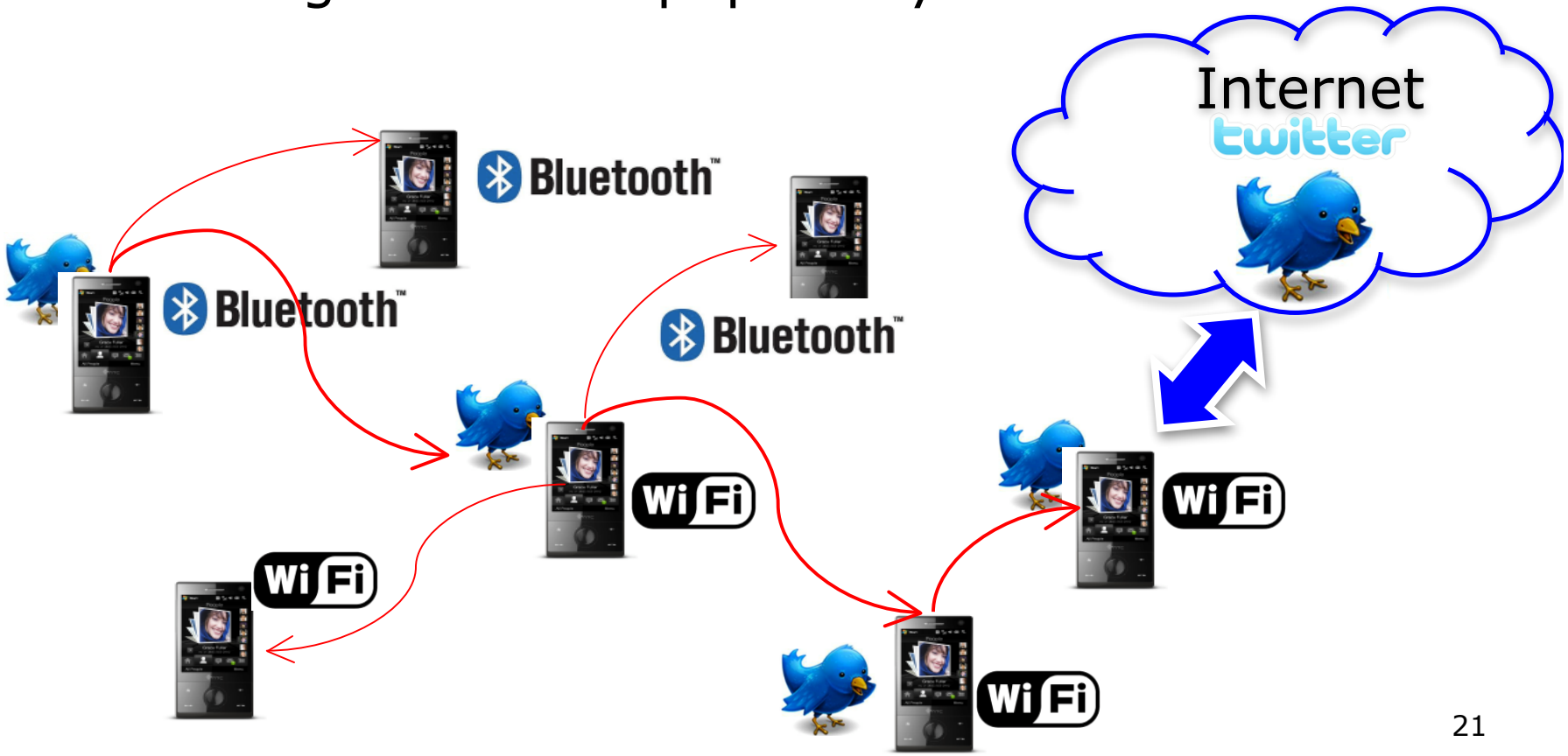
MobiClique SIGCOMM 2009 Vote

- 100 smart phones
- 45 topics, 12.8 votes per topic on



Haggle Twitter (EPFL)

- Twitter over Haggle + connection to online Twitter over the Internet
- Forwarding: based on popularity of Twitter channel



Conclusion

- Evolution: Pure forwarding → Content dissemination plus integration of social networking
- Optimisation of Epidemic Forwarding
  - SLEF (EPFL)
- Use of Social Structure in Forwarding
  - BUBBLE RAP (CAMCL)
- Context Aware Forwarding
  - PROPICMAN (SUPSI), HiBOp (CNR)
- Content Centric Approach
  - Content Place (CNR)
  - Socio-aware Overlay (CAMCL)
  - Content Centric Networking (Uppsala)
  - MobiClique (Technicolor)
  - Opportunistic Haggle Twitter (EPFL) with Online Twitter