Resource Discovery in Activity-Based Sensor Networks

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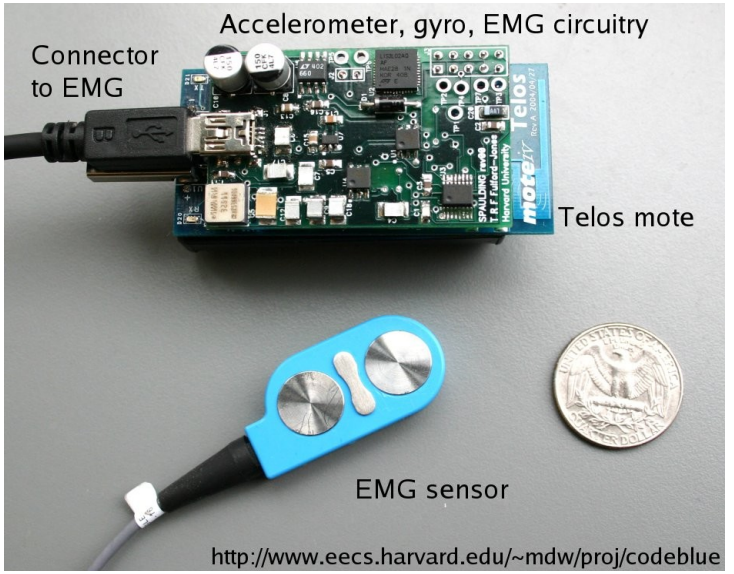
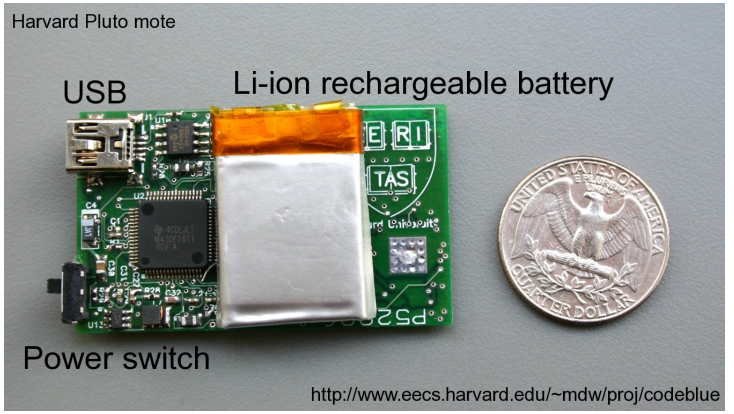
Sensor Networks in Healthcare

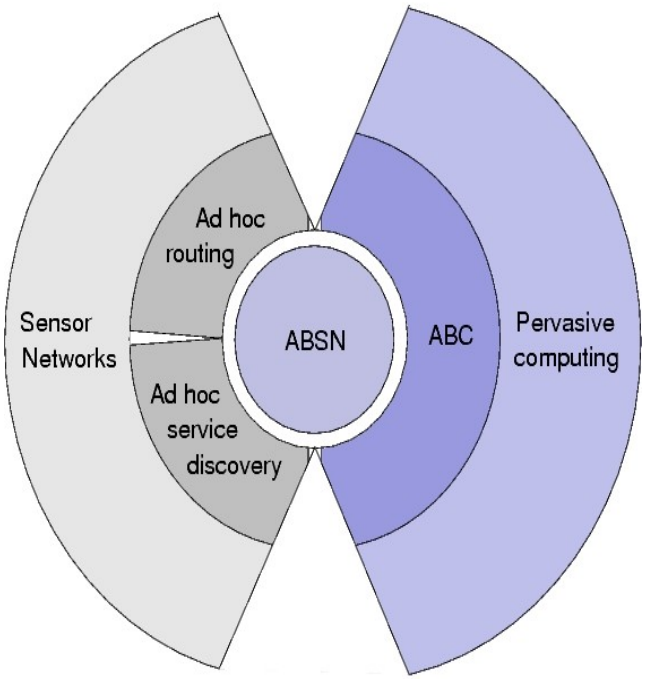
- Body Sensor Networks (BSN) are designed for prophylactic and follow-up monitoring of patients in:
  - their homes
  - during hospitalization
  - in emergencies
- Medical sensors for patient monitoring in emergencies
  - the European FP6 PalCom
  - Code Blue at Harvard



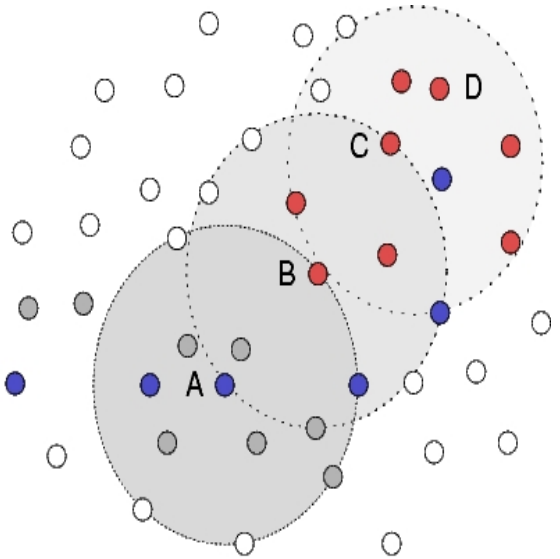


An early summary

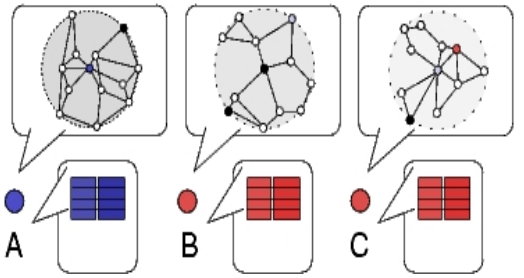
Motivation



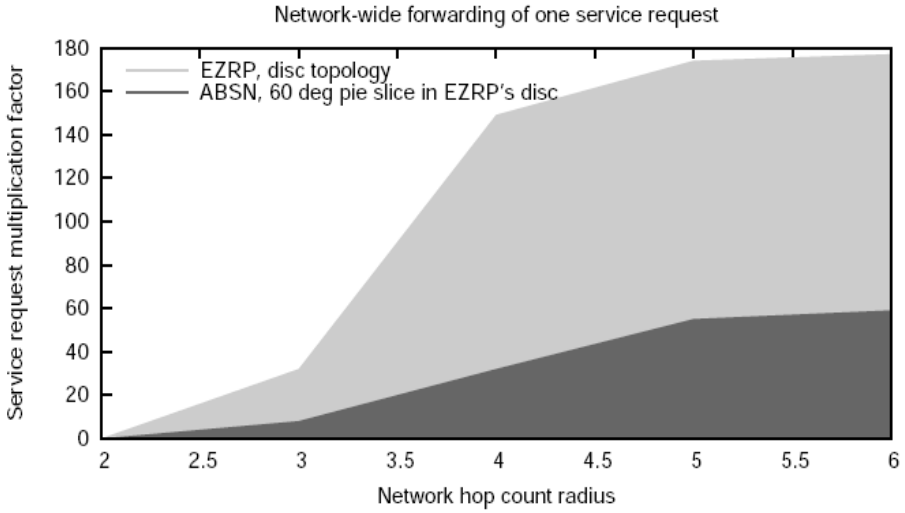
Protocol design



Routing graphs and service tables:



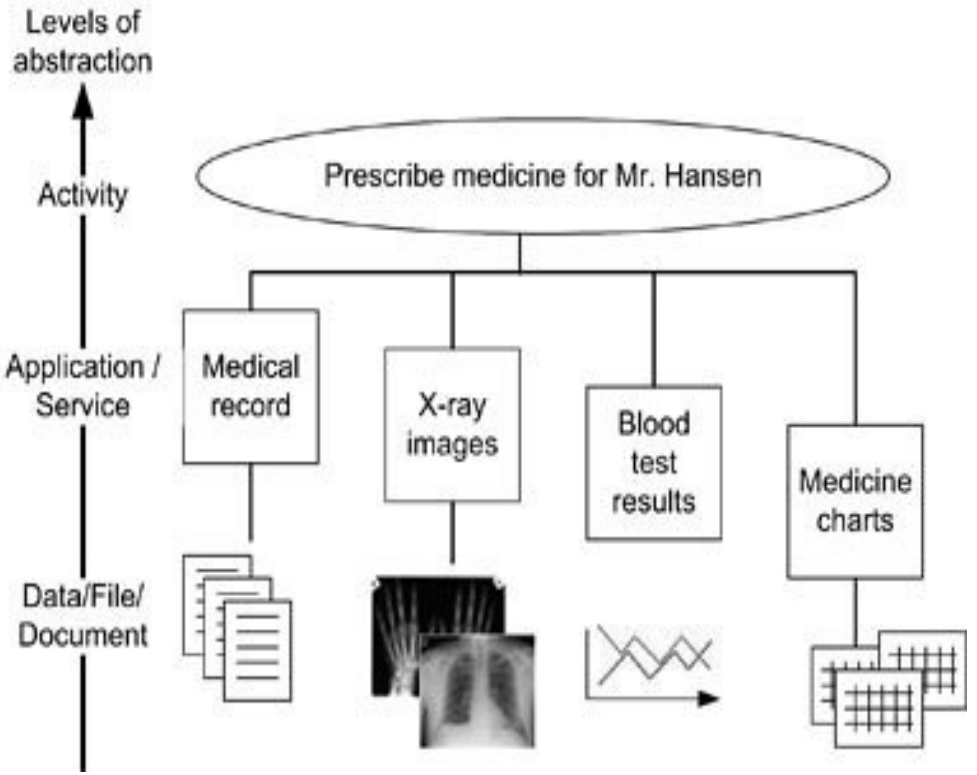
Evaluation



Activity-Based Computing, ABC

- Activity-Based Computing : a new paradigm for computing, more suited for ubiquitous computing.

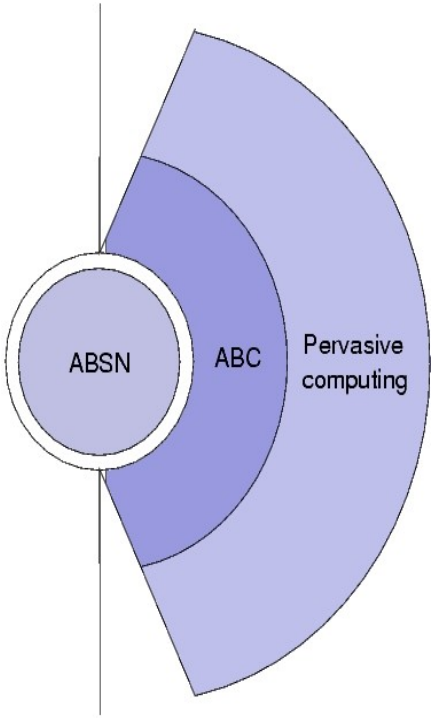
- Traditional computing: application- and file-centered paradigm, oblivious to a notion of user tasks spanning heterogeneous
  - devices
  - applications or services
  - data sources.



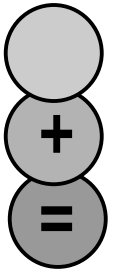
- Motivated in creating pervasive computing support for hospitals, but has much wider applications than the medical domain.

Activity-Based Sensor Networks, ABSN

- ABSN uses the high-level concept of computational activities to push for a new networking paradigm:
  - sensors are aware of their task even at the network layer,
  - which then optimizes networking



– It sums unrelated fields:



"classical" ad hoc discovery protocol

a new, "pervasive" computing paradigm

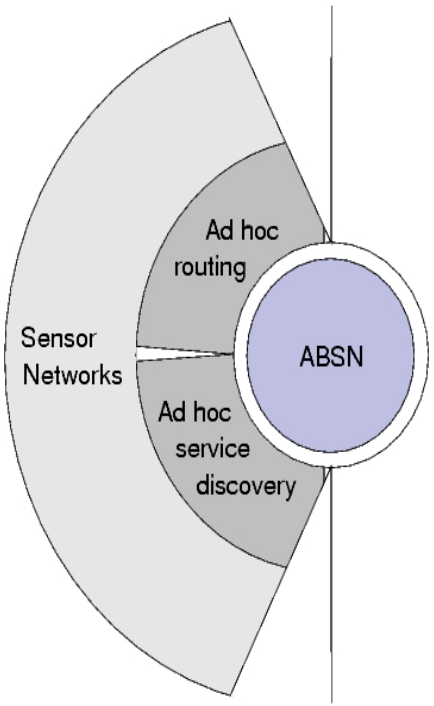
"pervasive" discovery paradigm

ABSN: Usage Case

- Motivated by PalCom
- A healthcare activity could be:
  - the in-hospital prophylactic monitoring for congestive heart failure by combining parameters such as blood pressure, ECG, weight, pulse
  - the environmental sensors in a hospital
  - the monitoring activity for each victim in an accident by bundling sensors monitoring respiration, pulse, oxygen saturation, temperature, and blood pressure
- Sensors are dynamically grouped to destination by nurses
- Serves both ad hoc (primarily) and infrastructure settings, in an integrated fashion

Sensor Networks

- Sensors come:
  - resource-limited
  - range-limited
  - in large numbers



- Core research questions in ad-hoc sensor networks (MANETs) include low-level
  - data routing protocols and
  - service discovery protocols,

  i.e. the way to most efficiently - in terms of
  - response time
  - network overhead and
  - power consumption -

  route data and discover services within the network.

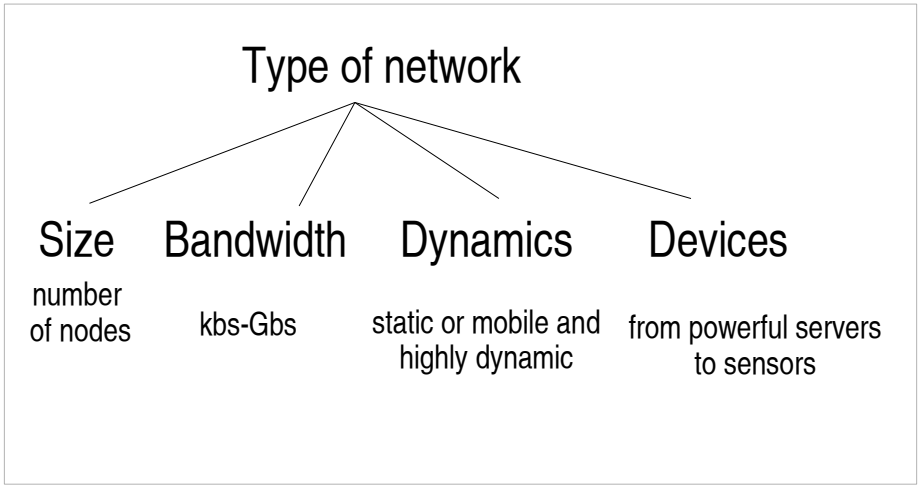
Sensor Networks: Routing

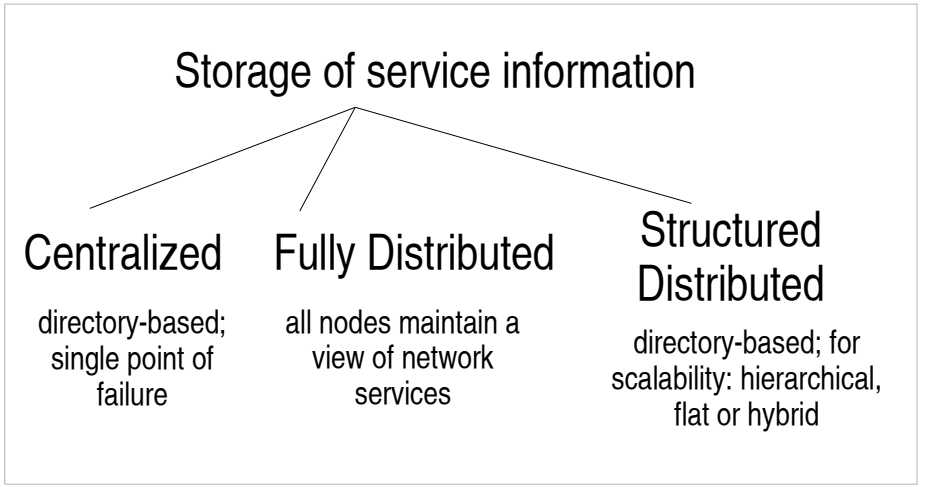
- In ad hoc networks,
  - nodes do not have a priori knowledge of topology of network around them;
    - discovery is needed
  - the network is large and multihop
- Ad hoc routing is:
  - proactive (periodic, flooded updates)
  - reactive (flooded search on demand)
  - hybrid (limitedly proactive, limitedly reactive)
  - and more: hierarchical, geographical, power aware, multicast, geocast

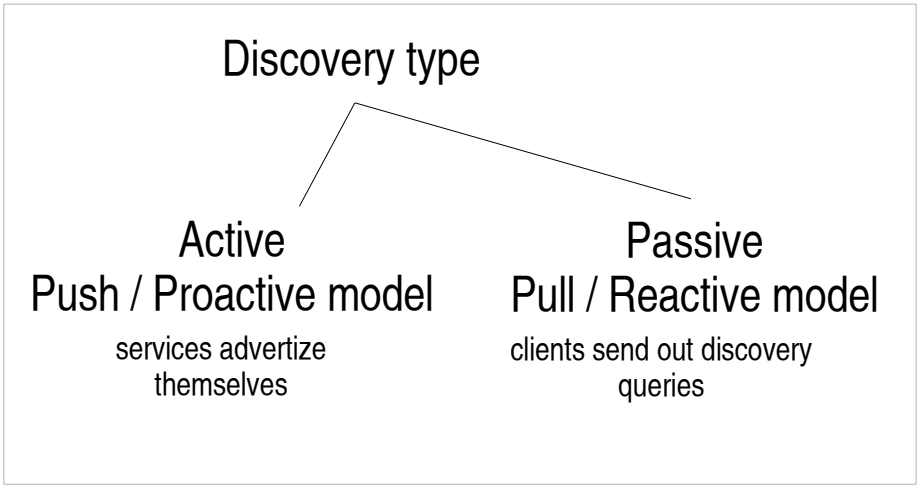
Sensor Networks: Service Discovery

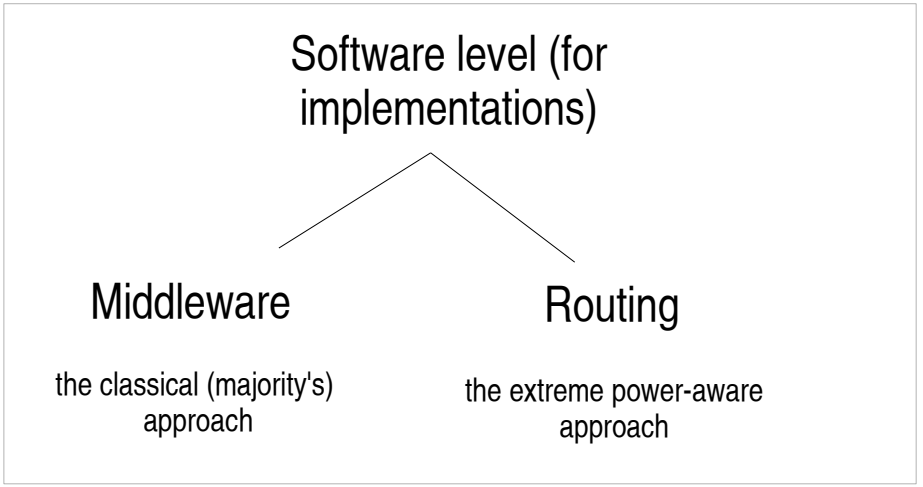
- Service discovery helps a mobile user to
    - take advantage of local resources
    - adapt to network change
- “Classical” service discovery:

Service discovery – a basic taxonomy









Service discovery – a taxonomy

	Type of network	Storage of service info	Discovery type	Service information state	Service naming	Service usage
Jini	Enterprise network	Centralized	Both active and passive discovery to locate the Lookup Service	Soft state	Java objects	Lease-based
UPnP	Enterprise network	Unstructured distributed (P2P)	Both active and passive discovery to locate services	Soft state	XML description based on UPnP template language	Explicitly released
SLP	Enterprise network	Both centralized (w DA) and P2P (w/o DA)	Both active and passive (w DA) and active (w/o DA) discovery of services	Soft state	Service templates registered with IANA	Explicitly released
Bluetooth SDP	Small network, 8 low-power devices	Centralized	Active, request/response client/server	Soft state	Service attributes (ID-value)	-
Salutation	Any network	Flexible (P2P or centralized)	SMP protocol between SLMs	Hard state	Service description records	Explicitly released
INS	Dynamic and mobile	Hybrid (spanning-tree overlay network)	Passive service discovery	Soft state	Attributes and values	-
Ninja SDS	LAN	Hierarchically decentralized	Both active and passive discovery	Soft state at leaf directories, hard state at others	-	-

Sensor Networks: Service Discovery

- Service discovery helps a mobile user to
  - take advantage of local resources
  - adapt to network change
- “Classical” service discovery:
  - has services register to a directory (on powerful static machines)
    - in MANETs mobility and resource poorness disallow directories
  - is primarily [semi]centralized, registration-oriented and assume the underlying network to be stable
    - MANETs require a decentralized design in which a node should not be depending on other nodes
  - are heavyweight (bandwidth and battery-wise)

Adhoc/sensor service discovery – a taxonomy

	Size of network	Storage of service info	Discovery type	Software level	Energy policy	Service naming	Implementation
DEAPspace 2001 IBM Research	Single-hop short-range, very small network	Decentralized, unstructured: all nodes keep all services	Active broadcast; periodical adverts and caching on nodes	-	Periodical sleeping between adverts	-	-
Allia 2002 U.Maryland	IP over Bluetooth, GSM, 802.11	Decentralized: each node caches services in its vicinity based on a policy	Active broadcast periodical adverts and policy-based caching on nodes	Middleware	-	-	IP m-commerce
Cheng's SAD 2002 Lehigh U.	over multicast IP	Partial storage, de-centralized, un-structured	Pull-based, + only updated service adverts	Routing, SD piggy-backed on ODMRP	Light embedded routing+SD	Simple name and attributes	-
Konark 2003 U. Florida	over multicast IP	Decentralized, unstructured: all nodes cache all services	Both push and pull	Middleware	Smart adverts	XML, delivery over HTTP servers	IP m-commerce
Ext ZRP 2005 Athens	Multihop	Fully distributed by node caching	Push inside a node's zone, pull at a global level	Routing	Embedded routing + SD; 50% savings compared to an application-level protocol	UUI; rich semantics is of no use	Simulated
CARD 2005 USCalifornia	Multihop	Fully distributed by node caching	Push inside a node's zone, pull at a global level	Routing	Light embedded routing + SD	-	Simulated

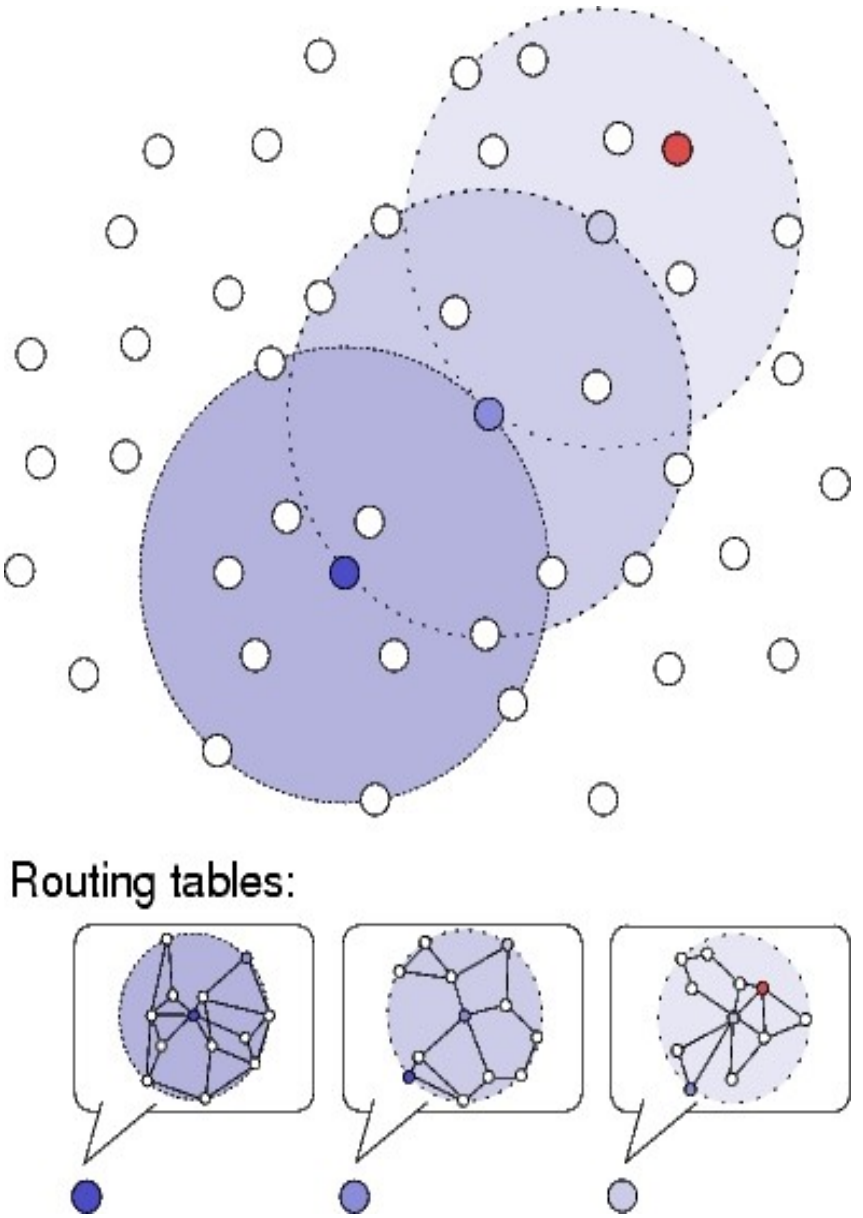
Enough background, let us design

ABSN:

- ad hoc network
- gateways are simple services
- network topology:
  - dense, relatively localized and connected sensor patches
  - network logically structured by activities (activity cluster, AC)
  - interaction among sensors often bounded inside an AC
  - network-wide discovery and data exchange
- high degree of mobility involving entire ACs at a time and of sensor unavailability

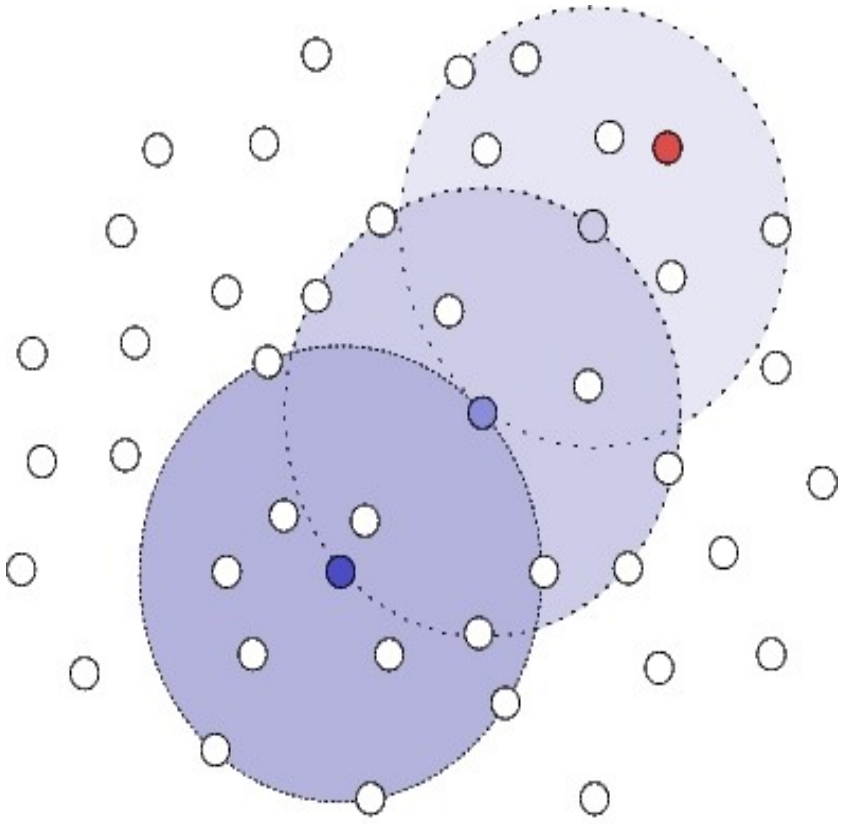
ABSN Build-up: ZRP

- ZRP (Zone Routing Protocol, IETF draft, July 2002) is a hybrid:
  - keeps a network zone of R hops around each node (heavily overlapped), and limits the proactive procedure to this zone
  - for out-of-zone discovery, queries are bordercast from a source node towards the edges of the network
- The IETF drafts give guidelines specific to routing over IP. We adapt these for sensor networks.

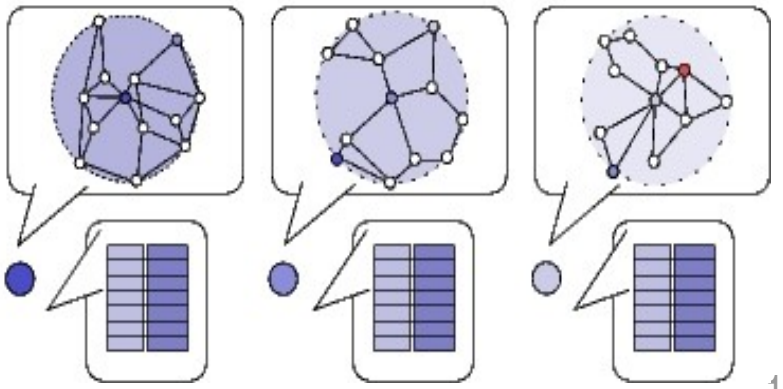


ABSN Build-up: EZRP

- EZRP (Extended Zone Routing Protocol, 2005)
- Idea: service discovery can be greatly enhanced by piggybacking service information into routing layer messages
  - "Service discovery in on-demand ad hoc networks", IETF draft, Oct 2002. No experimental assessment.
- EZRP extends ZRP for use in service discovery, simply by adding a service ID to the hello messages used by the routing protocol.

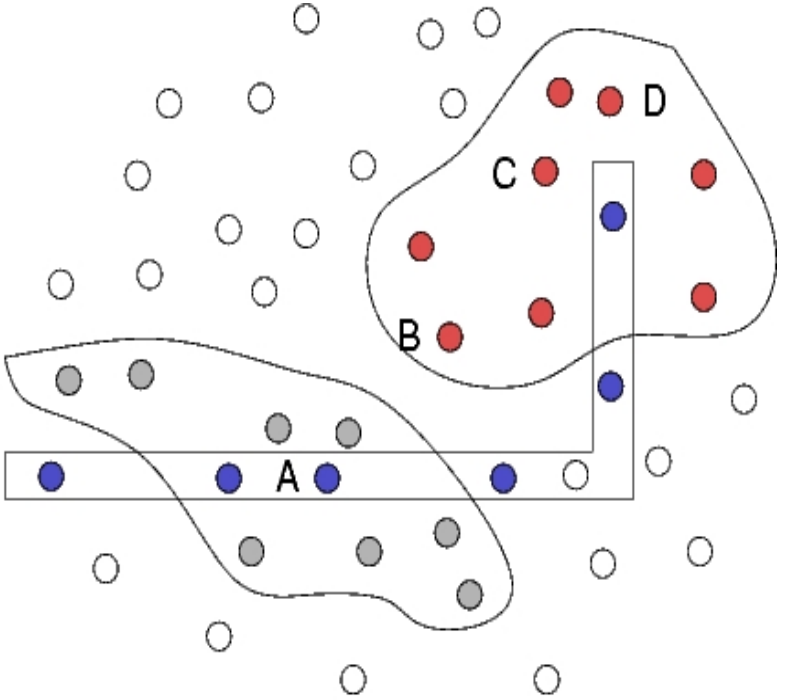


Routing graphs and service tables:

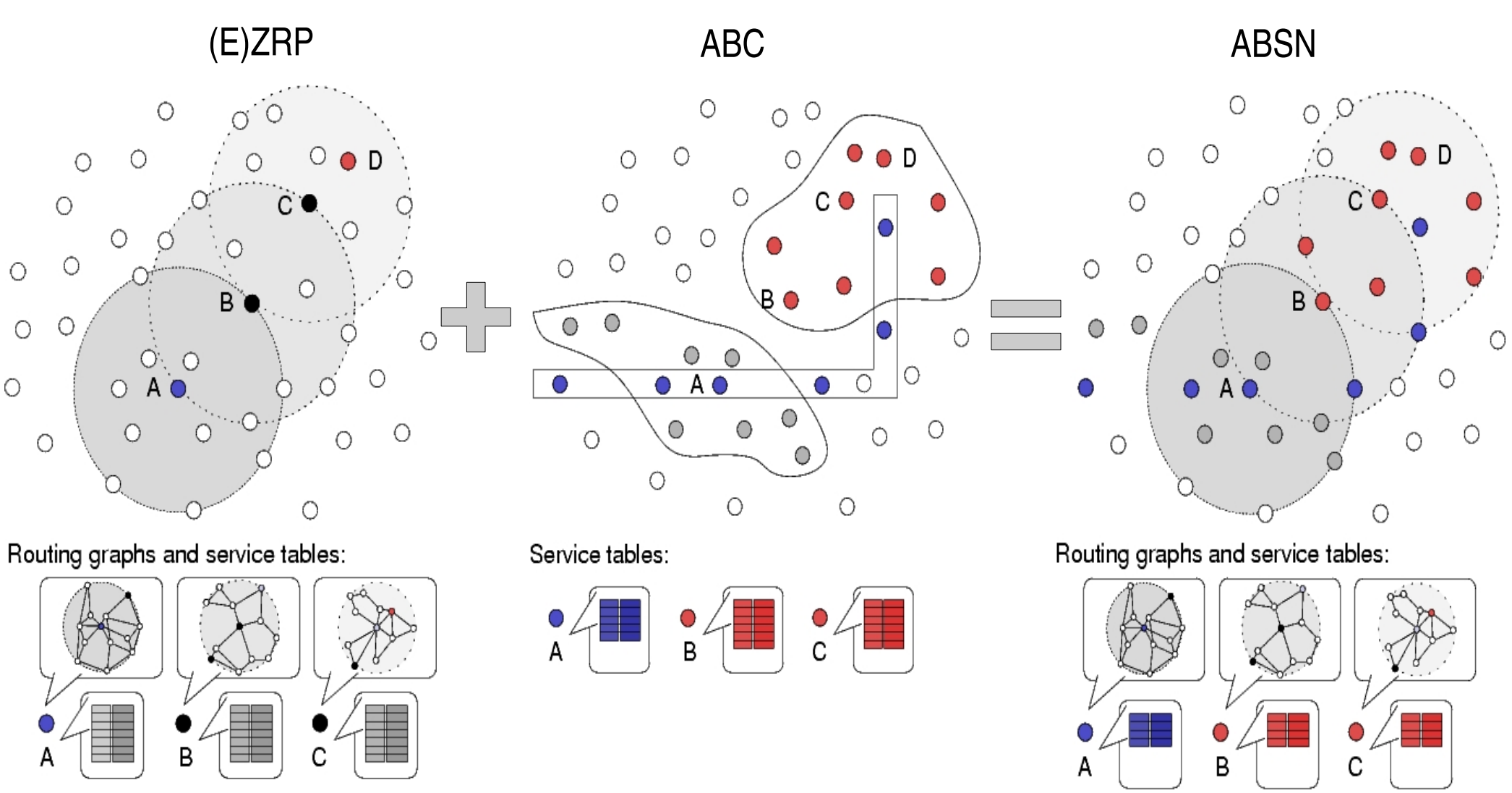


ABSN Build-up: ABC

- High-level activities reflect as logical grouping of the sensors into activity clusters, deployed in multihop, overlapping patches throughout the network.
- Although this might recall EZRP, activity cluster != network zone:



  - zones are sets of nodes reachable within a certain radius from any central node
  - activity clusters are unique sets of nodes (there is only one with patient Hansen's ID) and are deployed in irregular, possibly overlapping patterns in the network

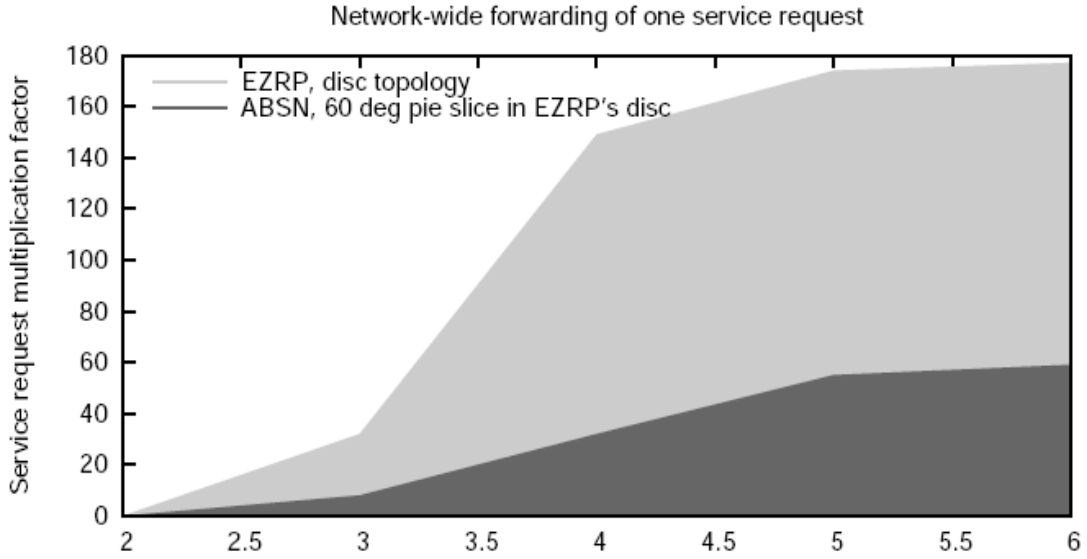


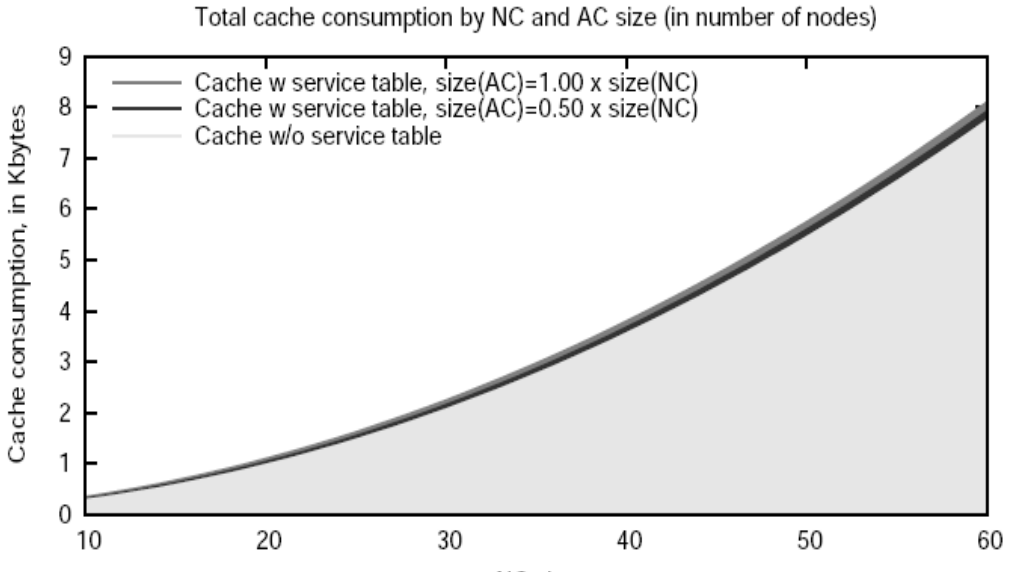
- A lightweight link-state proactive protocol is employed intra-zone, for every node to keep a routing map of the zone
- Also, hello and LSA packets carry the activity attributes of the nodes advertised, for every node to keep a same-activity service map of the zone.

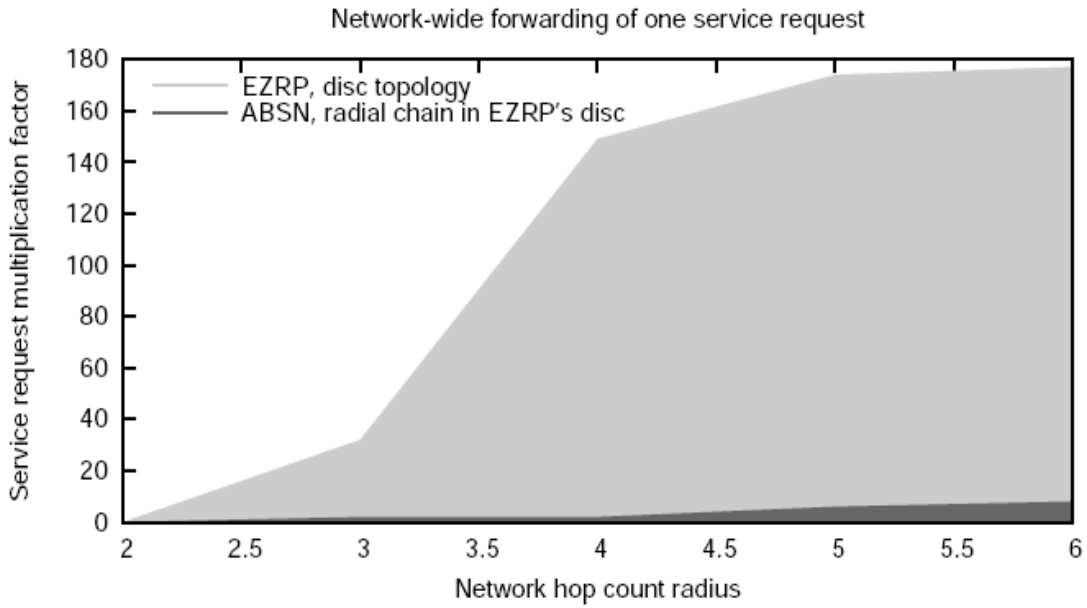
Route and Service Query Solving

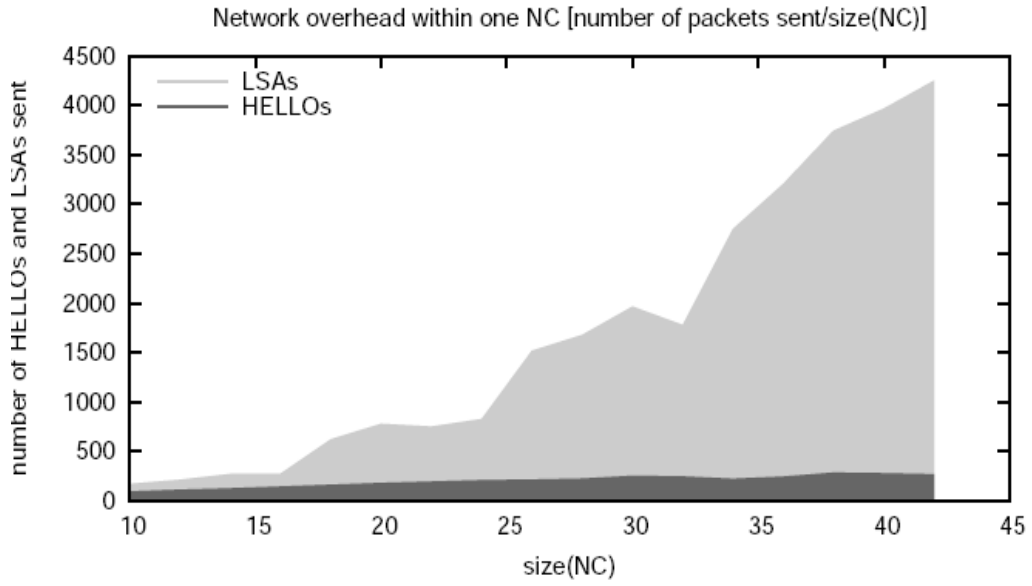
- Same colour service needed; the local service table is tried:
  - if there is a match, then the service owner's address is returned;
  - else, the query is bordercast only to the border nodes (or, if none exists, the closest nodes to the border) of the same colour, exploiting the fact that ACs are connected.
- Different colour service needed; the local routing table is tried for the closest node of the searched colour:
  - if such a node (gateway for the entire searched AC) is found, the query is relayed to it, and it will proceed as in the same-colour case;
  - if more than one gateway is found, ABSN chooses the closest gateway to the query source node;
  - if no such gateway exists, the query for the gateway is bordercast to all border nodes
- A routing query will be solved exactly as in ZRP.

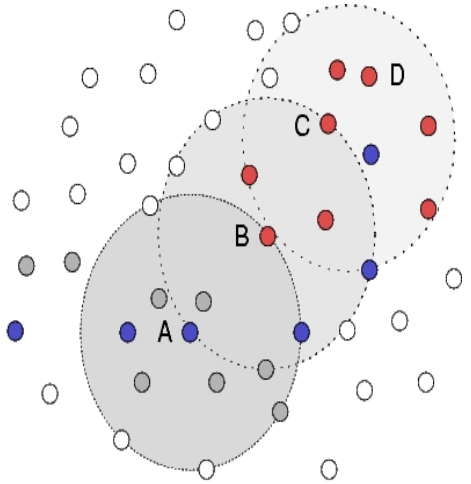
Discoverability, Optimality and Overhead Analysis











Thank You!

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