Personal Networks and Federations for Health

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TU Delft and WMC B.V., The Netherlands

MobileHealth
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Overview

- Introduction to Personal Networks
- The architecture of Personal Networks
- Networking
- Security
- Federations of Personal Networks
- Applications to health

A bit of history and acknowledgements

- Concepts presented originated in 2000 at Ericsson Research and TU Delft, The Netherlands
- Inspired by the work of Robin Kravetz at University of Illinois: Moped project
- Concepts worked out and prototyped in several large research projects: EU FP6 MAGNET and MAGNET-Beyond, and Dutch Freeband PNP2008 project
- Many small projects
- Parallel to Mobile VCE project in UK: Personal Distributed Environments (Irvine and Dunlop)

Technology drivers

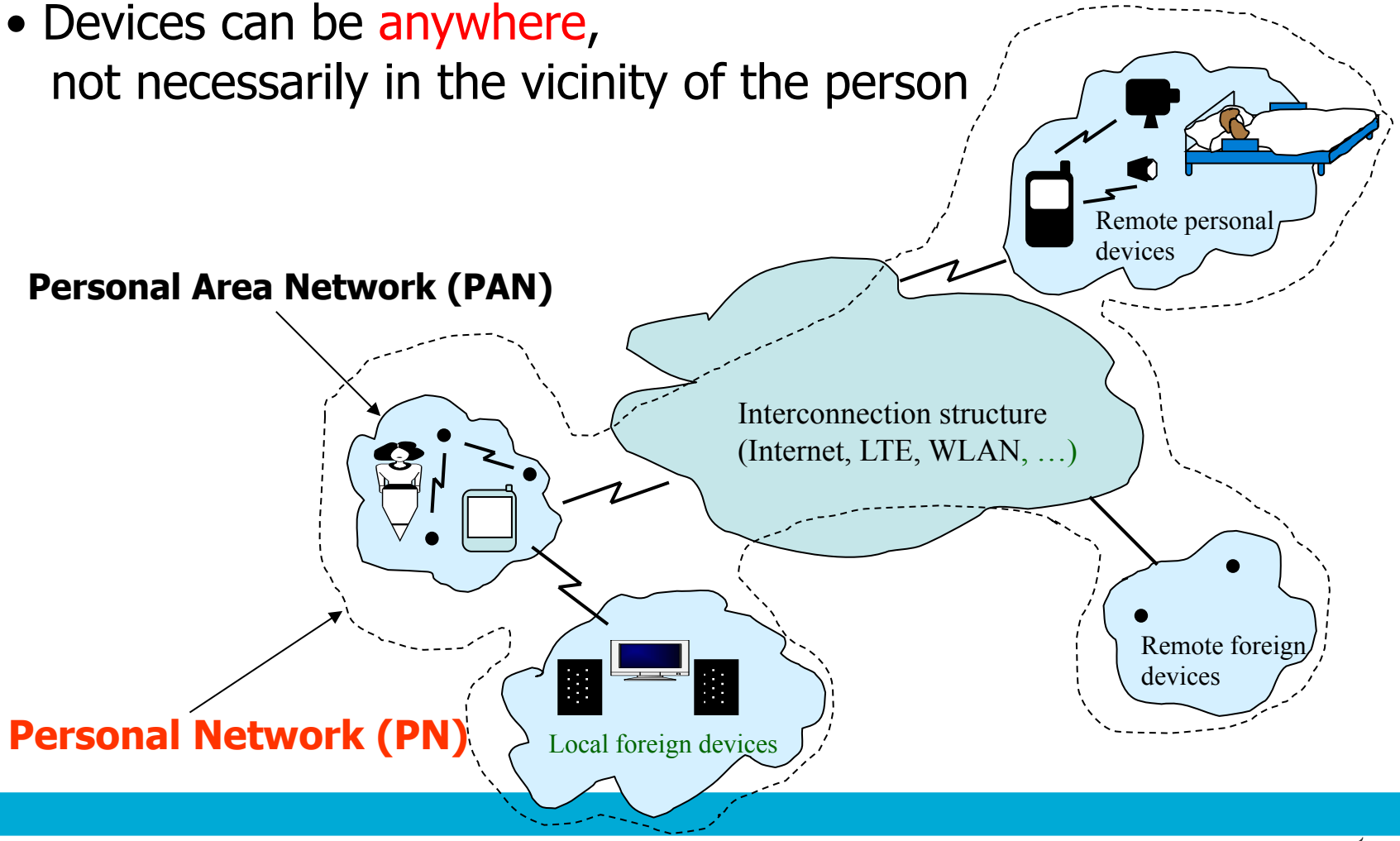
- Number and diversity of personal devices is growing tremendously (vision of pervasive computing, driven by Moore's law)
- Low cost air-interfaces covering a range of needs are becoming commonplace
- Infrastructure (Internet) access is becoming ubiquitous to fixed and mobile users, covering a wide range of user needs
- Growth of IP capable devices (e.g., IPv6 6LoWPAN)

What are Personal Networks (PN)?

- Devices belonging to a user self-organize to form a geographically distributed secure overlay network of personal devices
- A platform for a multitude of personal applications and services to support private and professional activities in a person-centric, unobtrusive, dependable and trustworthy way
- A tool to cooperate with others through federation and interact with non-PN systems (Federations of PNs)

Personal Network (PN)

- Network centered around a person and her/his needs
- Devices can be anywhere,
  not necessarily in the vicinity of the person



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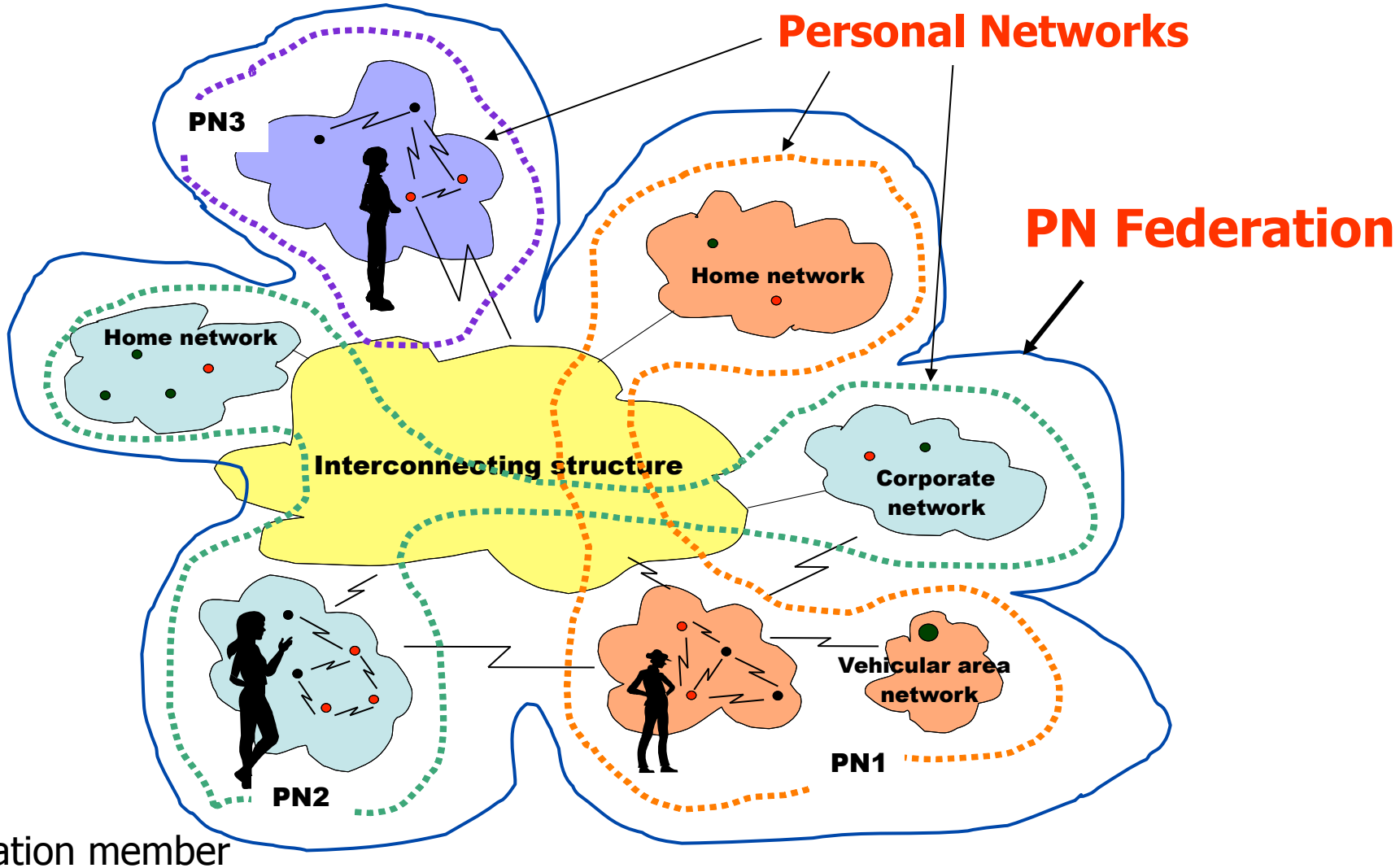
PN Federation (Fednet)



- Federation member

Key ideas of PN Federation

- Cooperation of multiple PNs
- Using selected resources and services of each other
- Driven by purpose or opportunity
- Temporary or long term for achieving a specific goal

TU Delft PN Prototype

- Software platform running on your devices providing:
  - Secure ubiquitous communication
  - Automatic configuration
  - Network technology independence
  - Integration with common operating systems (Linux, others under development)
- Developed at TU Delft over the past six years

Research projects with PN-like goals

- Universal Personal Networking (UPN): early 1990s at Siemens, no breakthrough
- Life-Works: more recent, Siemens
- Moped: University of Illinois, Kravets (2001)
- Personal Mobile Hub: IBM Research, Husemann et al. (2004)
- CoolTown: HP, Debaty and Caswell (2001)
- Mobile People Architecture: Stanford, Maniatis et al. (1999)
- Personal Distributed Environment: Mobile VCE, UK, Dunlop and Irvine (2003)
- MyNet: Nokia and MIT, Arvind and Hicks (2006)
- IST PACWOMAN and SHAMAN: EU FP7 (2002)

Commercial developments with a PN flavor

- Microsoft's Personal Cloud (2010 announcement)
- Intel' innovation vision
- Apple's MobileMe
- Drop Box (product)
- P2P Universal Computing Consortium (PUCC): Japanese universities and companies, e.g. NTT Docomo, NEC, Toshiba, since 2004, demo at CCNP 2008 CES
- 3GPP: Personal Networks as part of AIPN (2009)
- ECMA Technical Report on Personal Networks (December 2010)

PN architecture

PN Requirements

- Easy cross-device applications support based on service oriented architectures (SOA)
- Secure personal communication
- Automatic addressing and network configuration
- Routing, broadcasting and mobility
- Wireless technology and operating system independent
- Context-awareness
- Virtualization

Core Concept

- Distinguish between:
  - **Personal Nodes** – Devices owned/used/controlled by you
  - **Foreign Nodes** – All other devices
- One single and simple security system independent of link-layer technologies

Personal Network = The set of all Personal Nodes

Personalization of Nodes

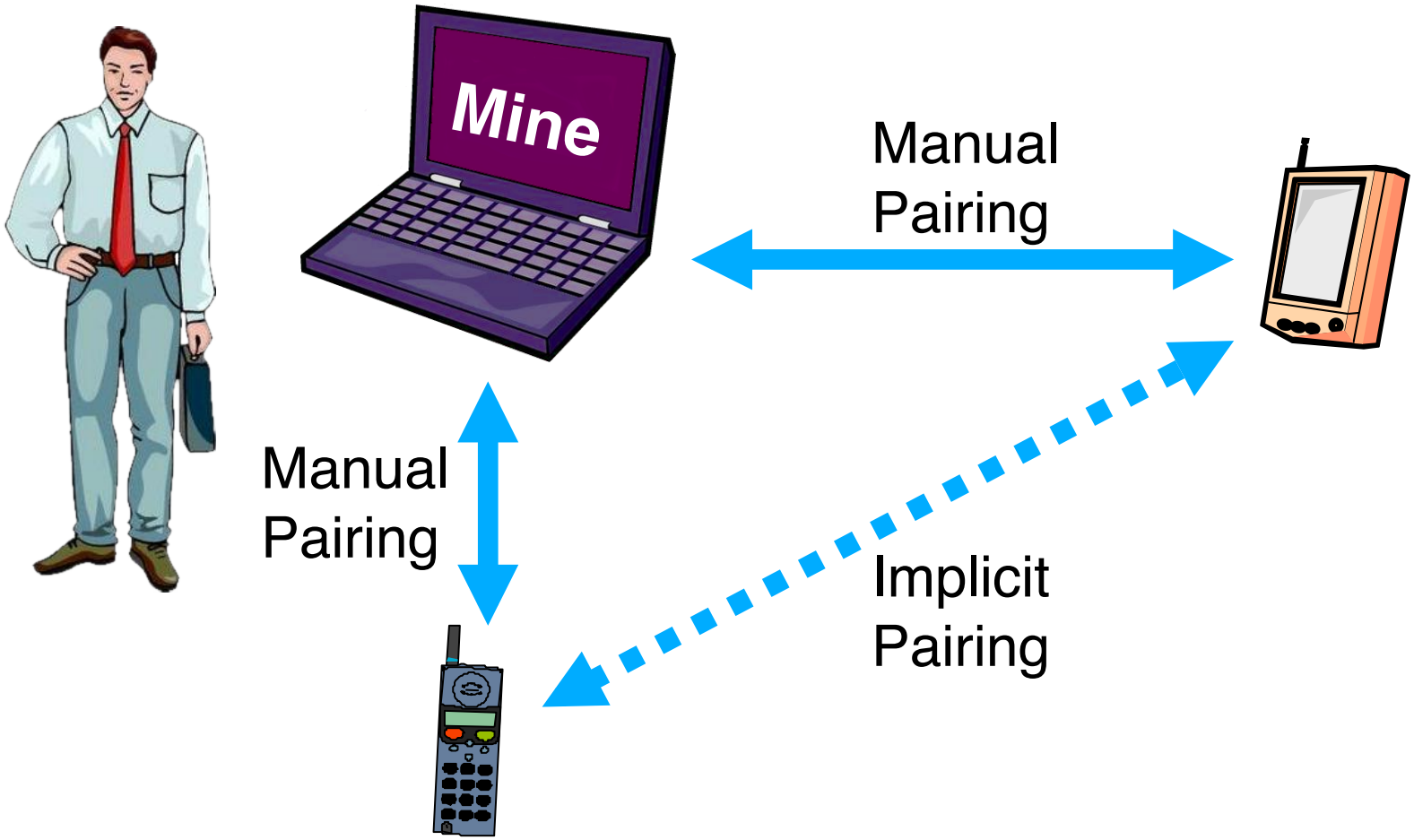
Cluster and PN Formation

- A security mechanism is used to separate Personal from Foreign Nodes. Clusters contains only Personal Nodes.
- A PN is formed by constructing inter-Cluster tunnels between Personal Clusters.

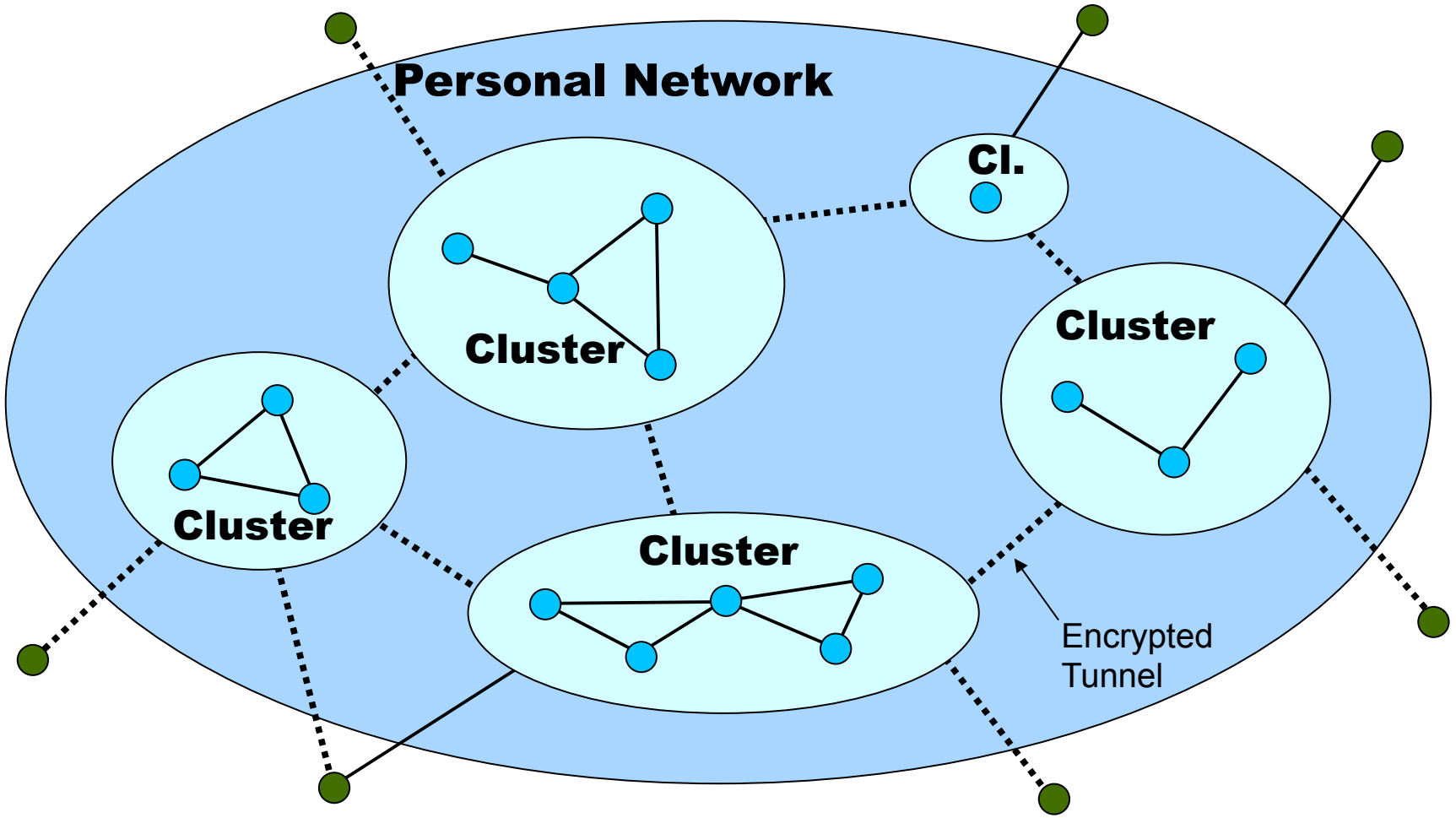
Personalisation

- A new Node is included into the PN (or personalized) by pairing it with a Node already personalized. It becomes a Personal Node.
- An intra-PN security mechanism makes sure that encryption keys are distributed to the new Node and that the PN is aware of the new Node.
- Configuration of a new Node (such as addressing).

Personalization of Nodes



The Network Architecture



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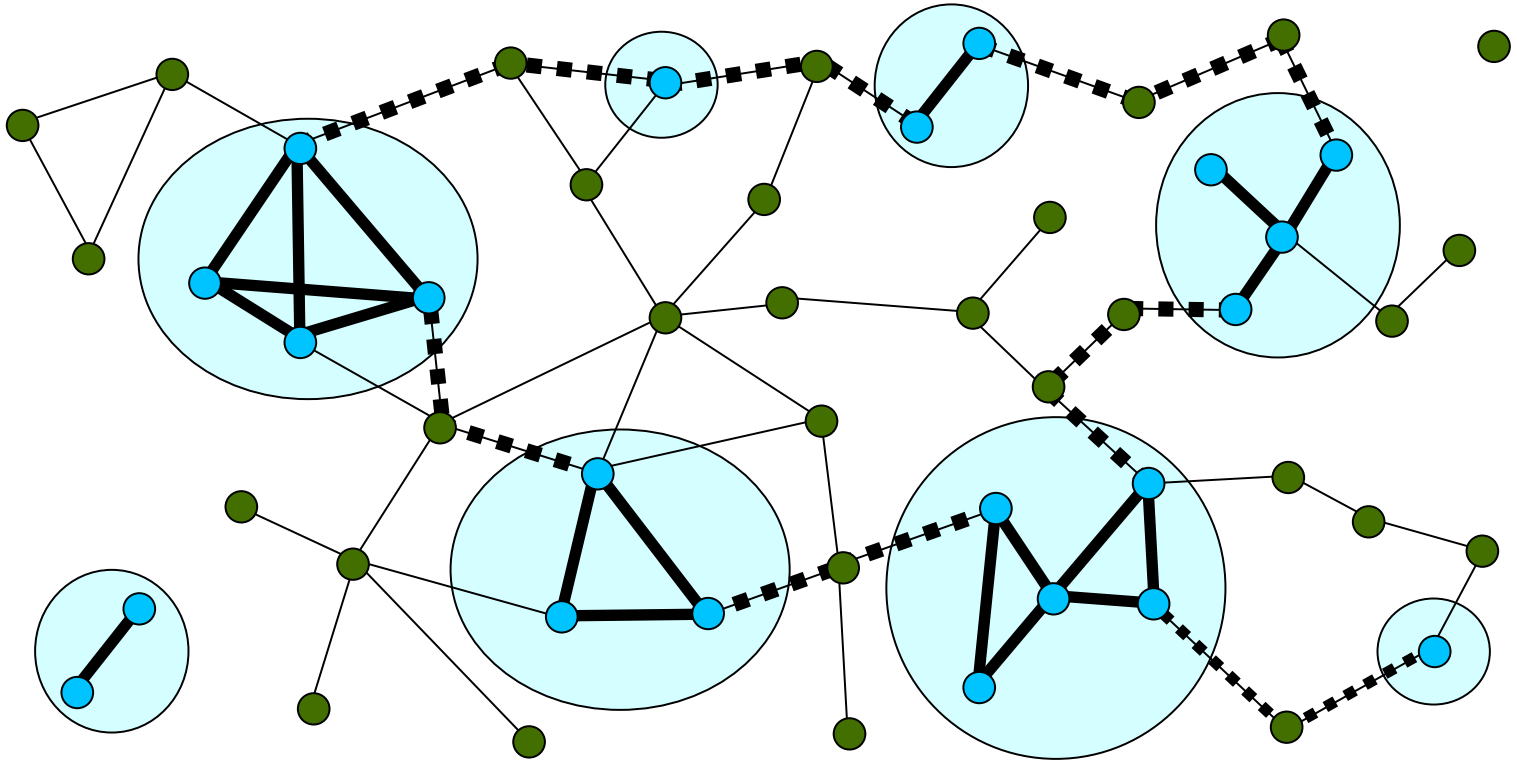
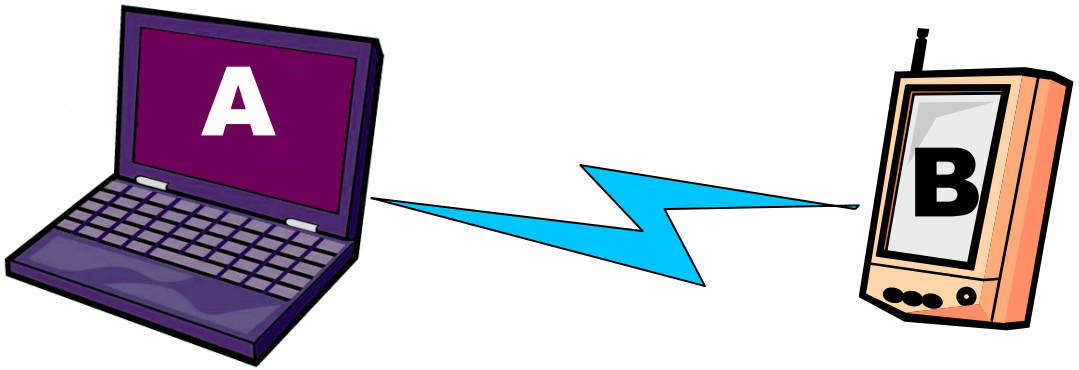
The Big Picture



When a Node meets another Node



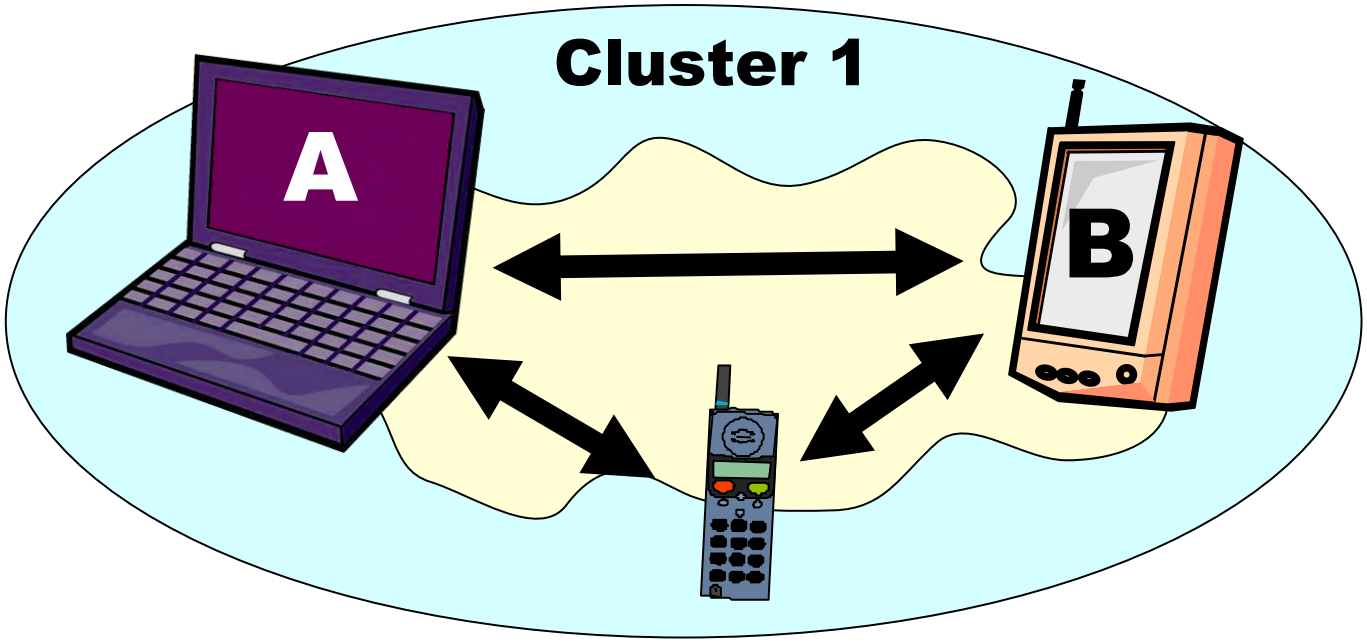
$\{\text{Hello, A}\}_{\text{PID}}$

$\{\text{Hello, B}\}_{\text{PID}}$

$\{\text{Mgmt Data}\}_{\text{PID}}$

$\{\text{Data}\}_{\text{PID}}$

Personal Networks



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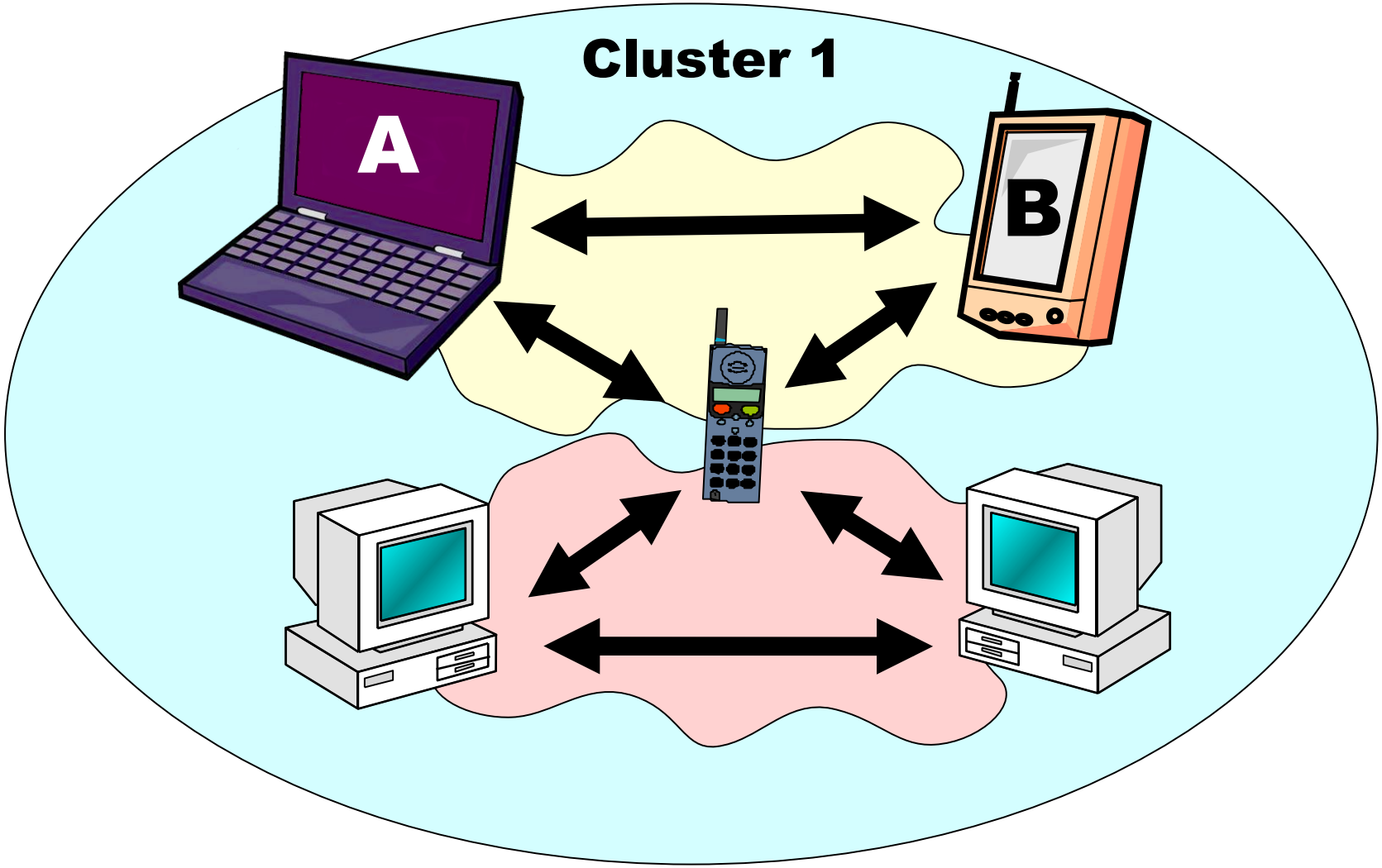

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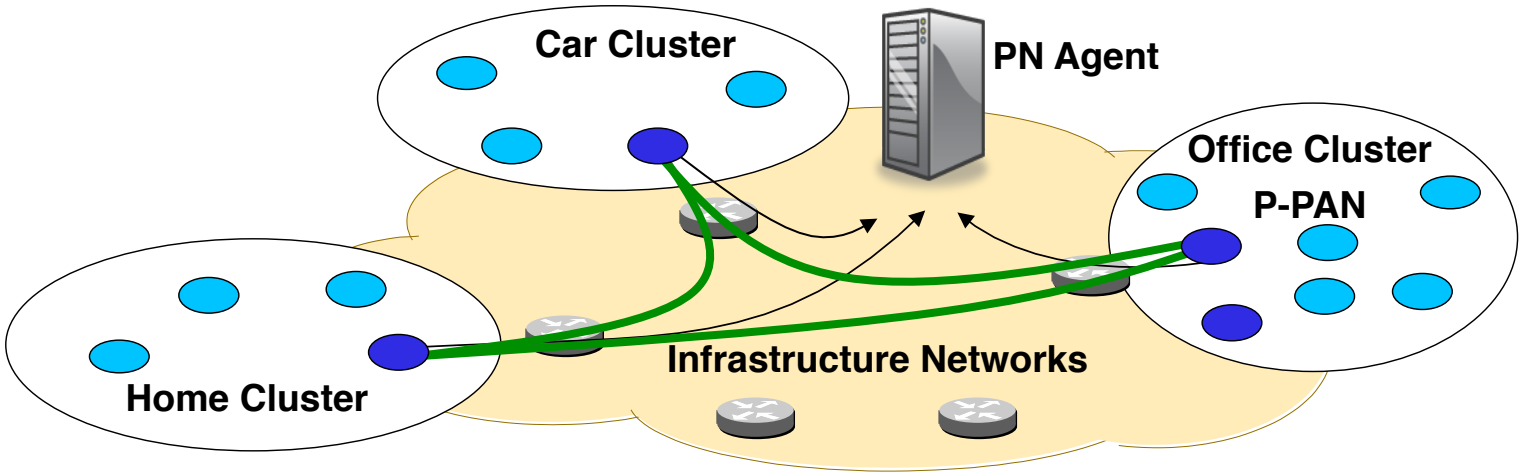
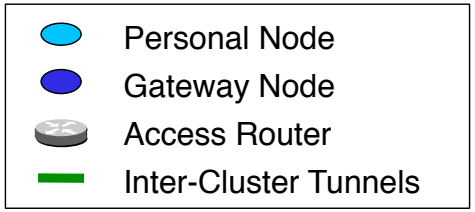
Personal Networks





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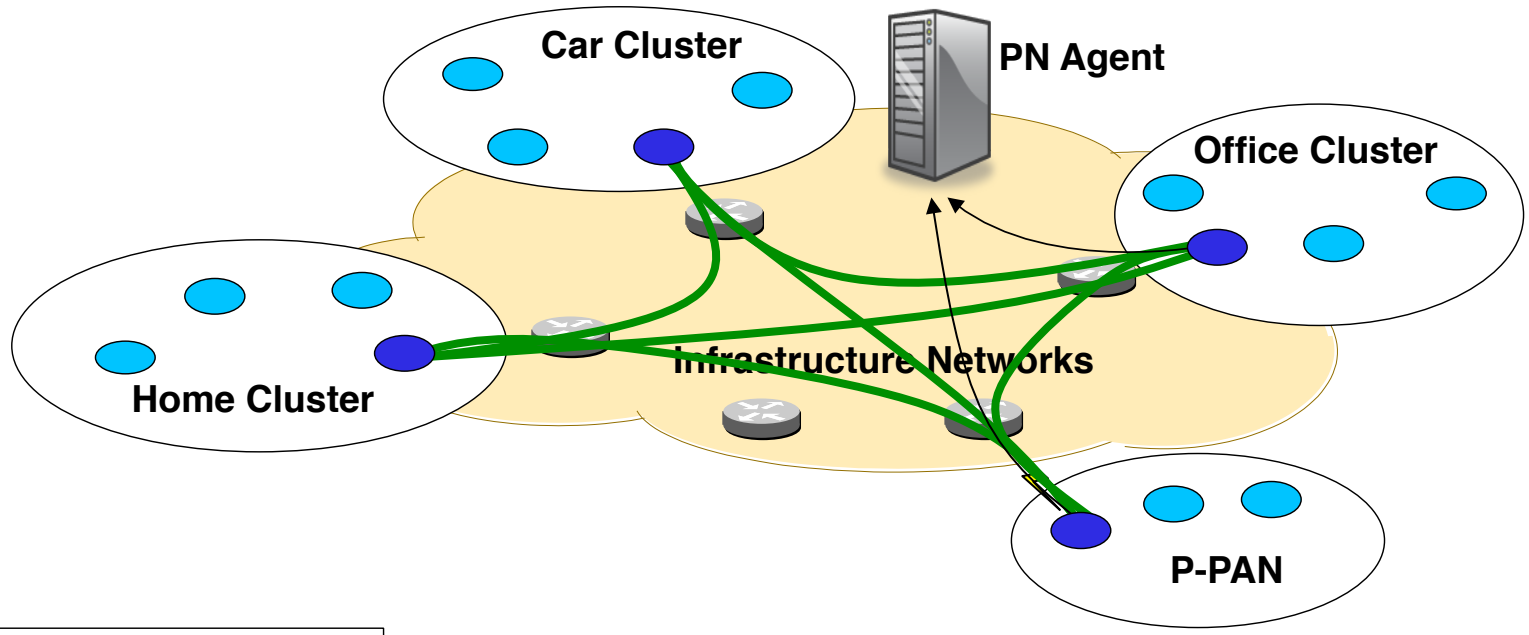
Personal Networks



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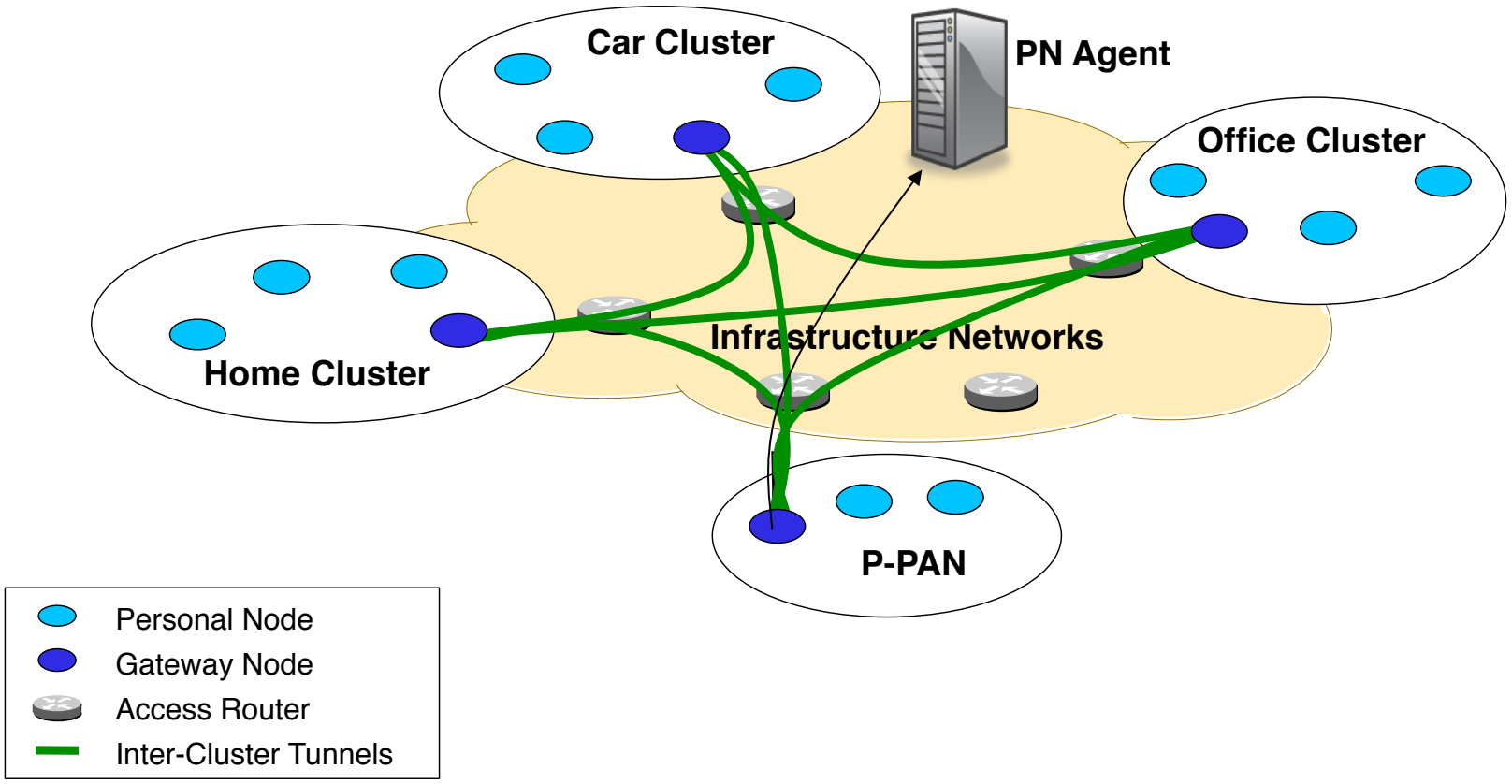
Personal Networks



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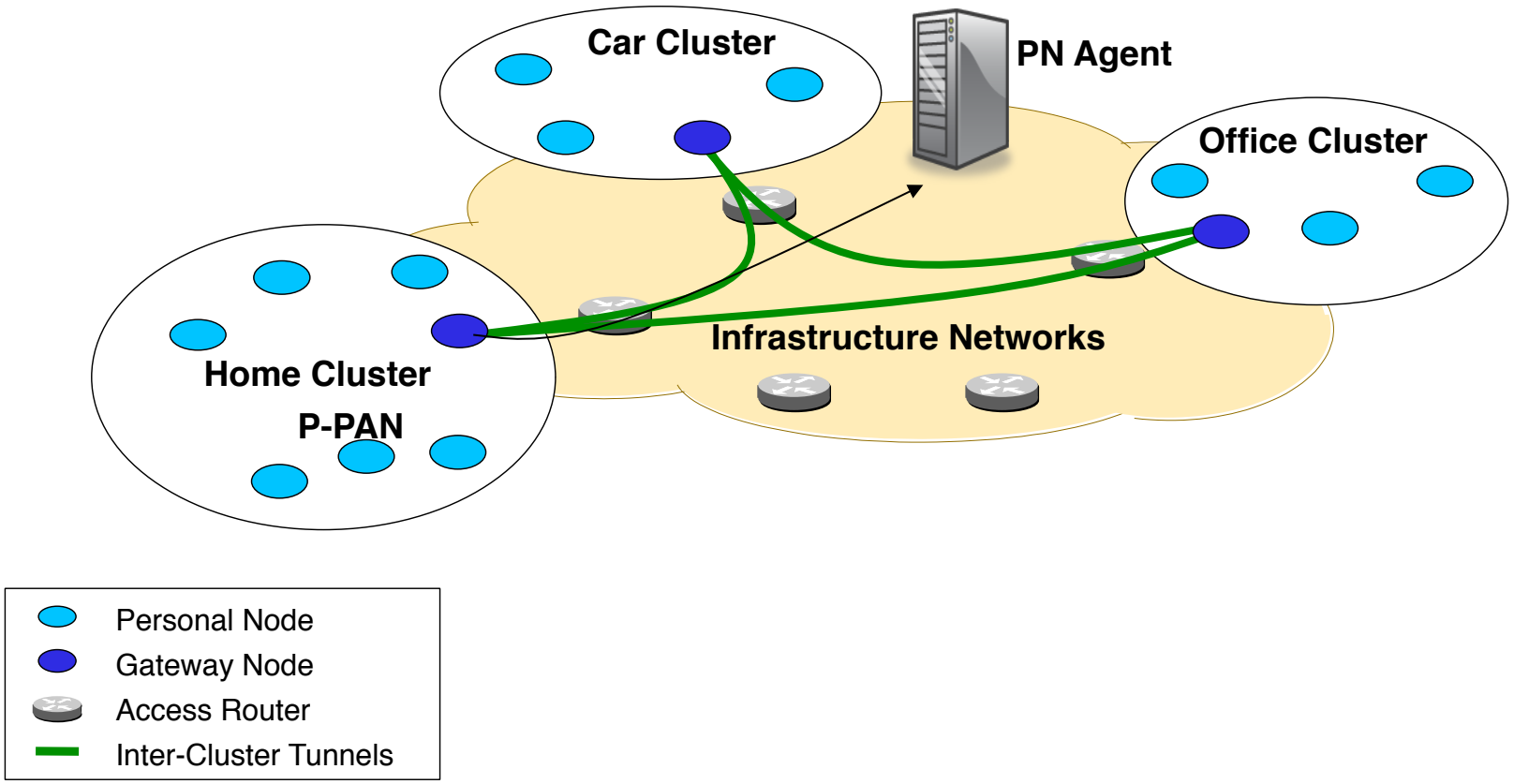
Personal Networks



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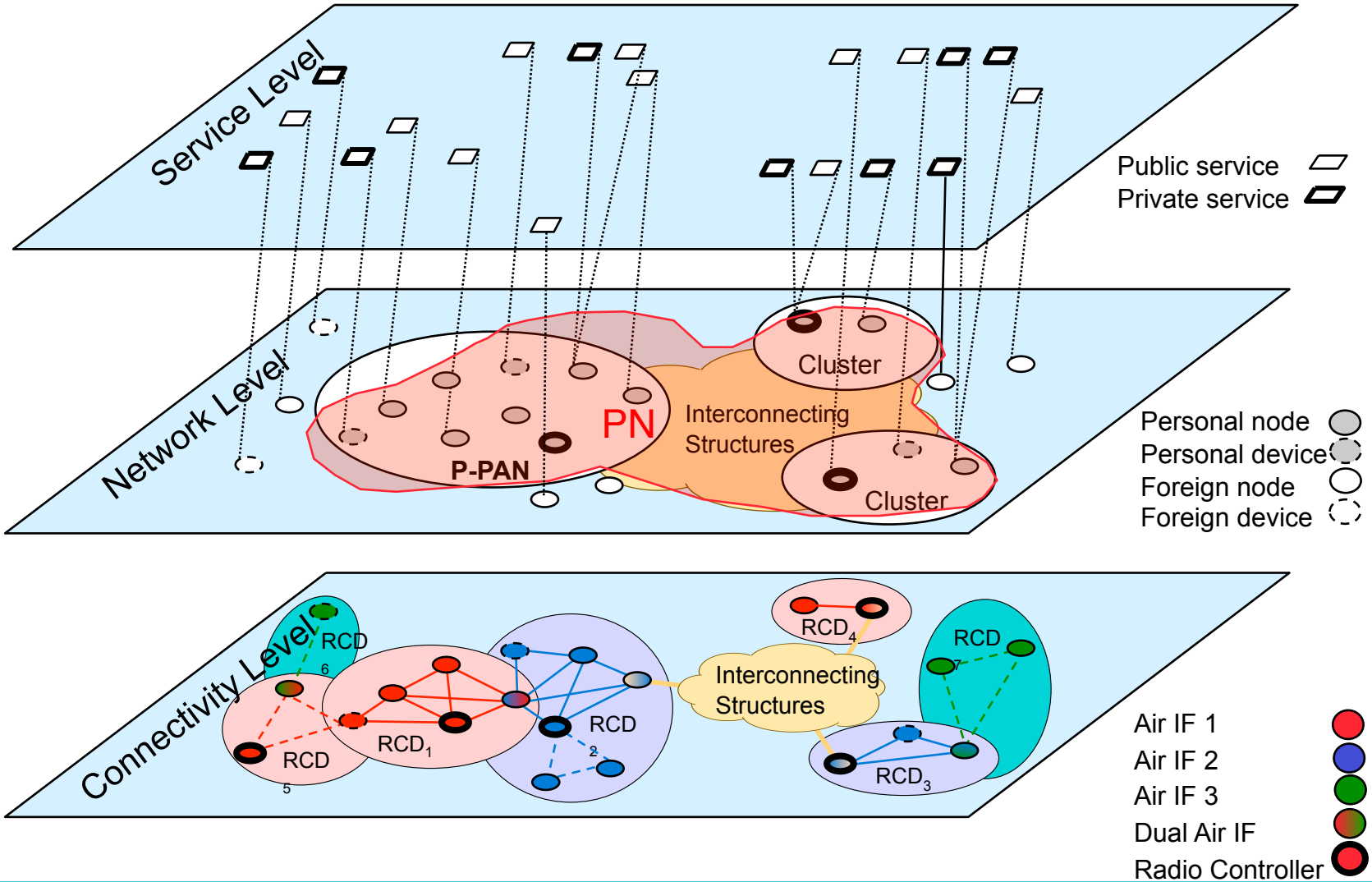
PN Networking

Three Layer View



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Addressing

- Each PN Node has an IP address
- Flat addressing within the PN
- Unique within the PN
- Assigned at the time of personalization
- Never changes
- TCP / UDP sessions are unaffected by mobility
- We used IPv6, but IPv4 is no problem

Cluster Routing

Mobile Ad Hoc (MANET) Routing

- Support Mobility / Dynamic Links
- Support Wireless / Heterogenous Links

MANET protocols used in our prototypes:

- OLSR – Optimized Link State Routing
- WRP – Wireless Routing Protocol

Proactive protocols work the best for clusters:

- Small and dense networks
- Many node-node flows
- Many short-lived sessions

Flooding

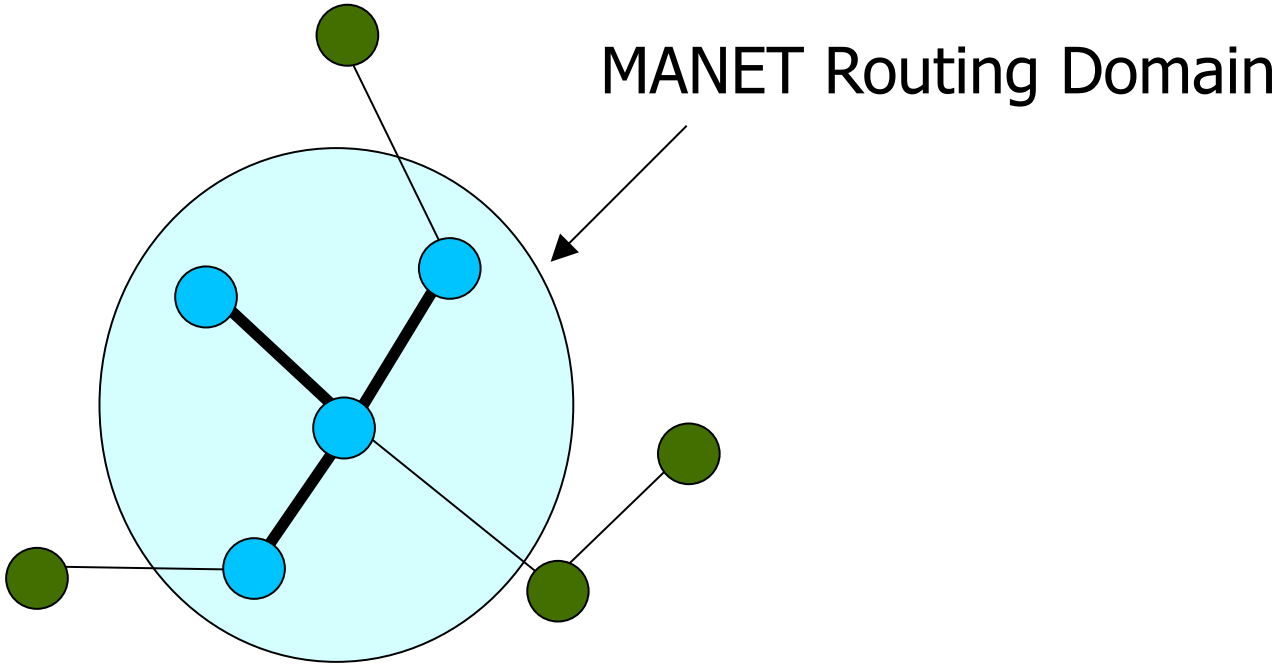
Cluster-wide / PN-wide Broadcasting

- Service discovery
- Context information dissemination
- Various network organization protocols
- Multicast applications

Existing ad hoc flooding protocols:

- Blind Flooding
- CBB – Counter-based Broadcasting
- SMF – Simplified Multicast Forwarding

Personal Node Recognition



Personal Node Recognition

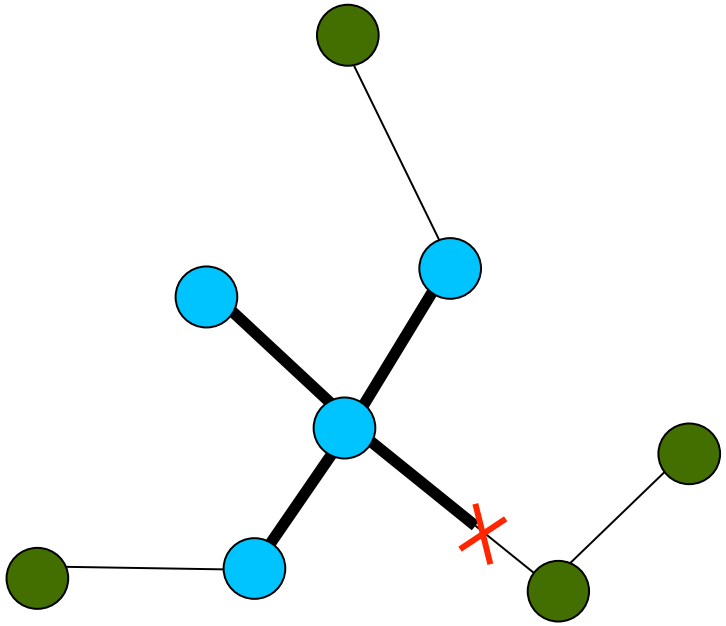
Personal Neighbour Node Authentication:

- Based on personalization
- Filter out the other neighbors
- Encrypt packets between personal nodes

Introduce a ”layer” below networking:

- Implements personal neighbour node discovery and authentication
- Expose higher layers (e.g. routing) only to authenticated neighbours
- MANET routing protocol can be unmodified

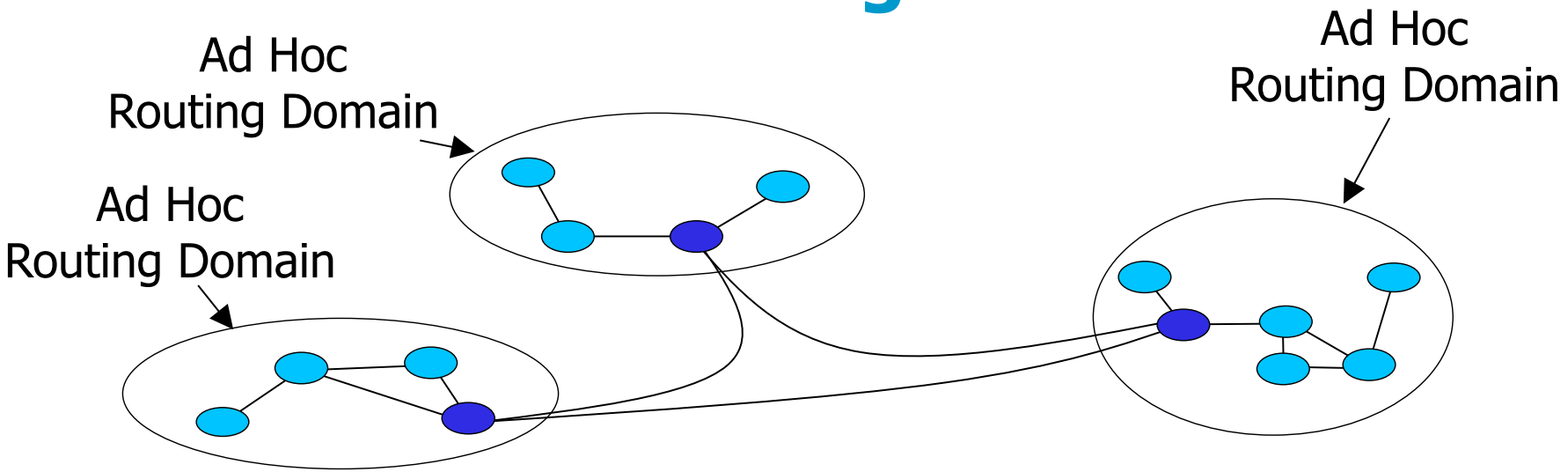
Personal Node Recognition



Inter-Cluster Tunneling

- Encrypt traffic over the Internet:
  based on keys established via personalization
- Supports mobility within PNs
- End-to-end packets (IP and upwards) are transmitted unchanged and tunnelled.

Inter-Cluster Routing

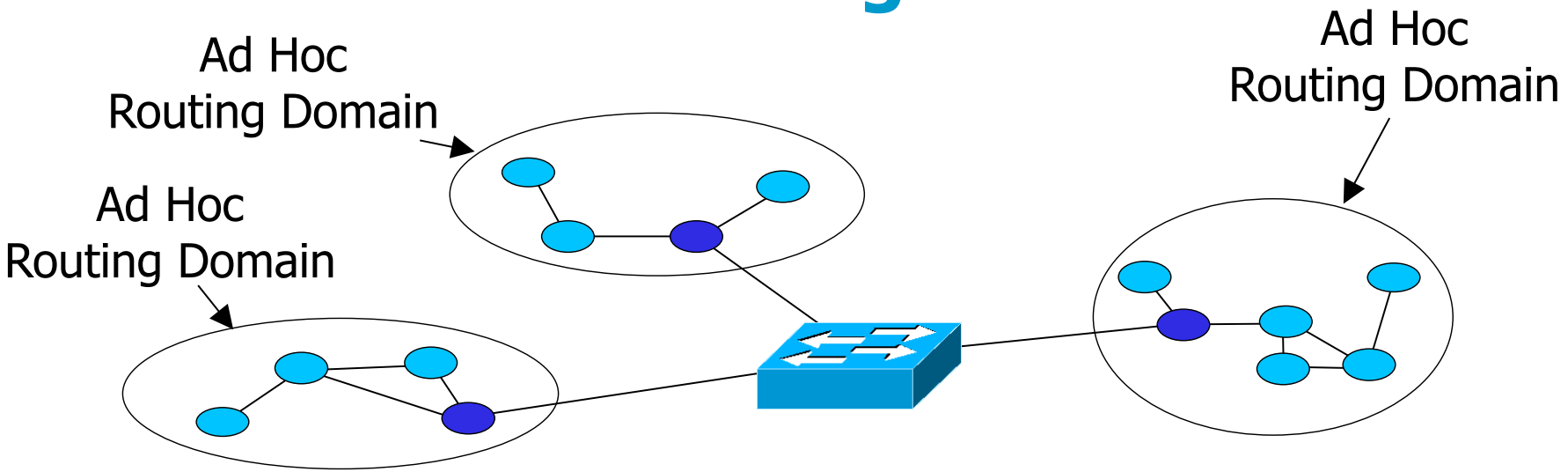


Flat Ad Hoc Routing across an entire PN is possible!

However, the tunnel links are special

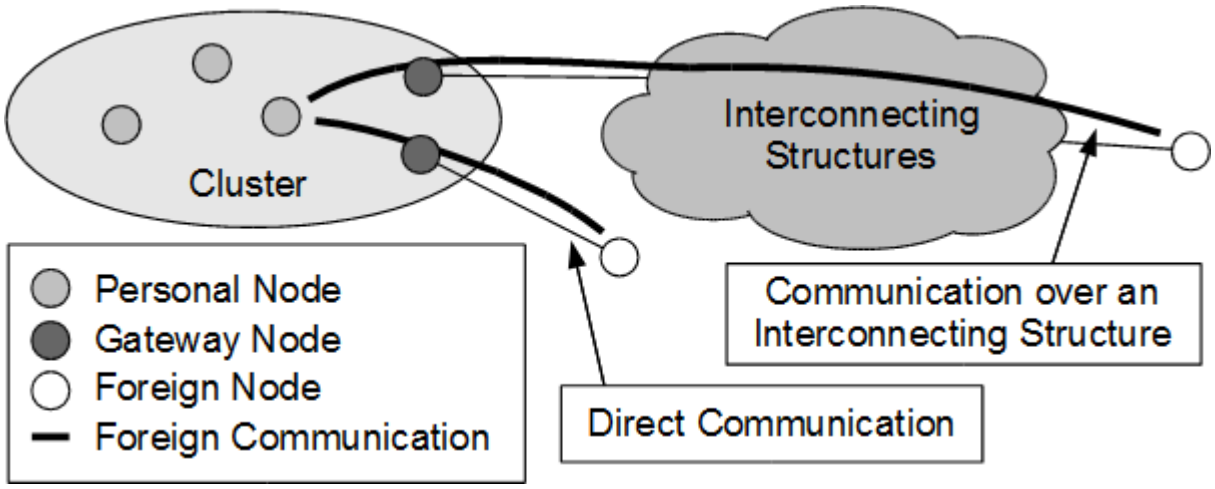
- Slow, usually the bottlenecks
- Most topology changes in a Cluster only have local consequences within that Cluster

Inter-Cluster Routing



- Each Cluster is its own ad hoc routing domain
- The tunnel inter-connect acts as a network switch
- Gateway Nodes keep track of which Node is in which Cluster
- Packets to Nodes in other Clusters are forwarded over the tunnels by the Gateway Nodes

Foreign Node Communication



Service vs. Network Level

Network Level:

- Using NAT/NAPT
- End-to-end IP connectivity
- Access control based on port numbers only

Service Level:

- Using Service-Level Proxies
- Two sessions instead of one (mainly problem for TCP)
- Finer granularity access control

PN security

PN Security

- Device personalization
  - Imprinting
  - PN Formation Protocol
  - Eviction of nodes
- Establishment of secure communication
  - Unicast
  - Broadcast
  - Inter-cluster

Imprinting

Based on the "**resurrecting duckling**" policy model (Stajano)

- A new device (**duckling**) starts in the un-imprinted state
- The device becomes imprinted when the first master device (**mother**) provides it with cryptographic material
- Other imprinting attempts will fail if the devices is imprinted state
- The master device can "kill" (remove the cryptographic material of) the device and bring it back to the un-imprinted state

Imprinting in PN

- Using public key infrastructure PKI adapted to the PN environment
  - PN certification authority (PNCA) signs the public key of duckling during imprinting
  - Generated certificate and PNCA certificate is stored in duckling
  - PKI light weight solutions with elliptic curve cryptography (ECC) (MAGNET Beyond project)
- Shared key
  - Pair-wise key with mother
  - Simple but with limited scalability

Certified PN Formation Protocol (PNFP)

- From European Project Magnet Beyond
- Two phases
  - Imprinting
  - Establishment of pair-wise keys

Eviction of personal nodes

- Certificates are issued by PNCA have limited life time: certificates need to be renewed
- For eviction before expiration of certificate:
  a certificate revocation list (CRL) signed by the PNCA is sent to all nodes in the PN using PN-wide broadcasting

Secure broadcast

- Use of unicast-only flooding protocol:
  reliable but not efficient
- Distribute a cluster-wide broadcast key:
  key distribution may be a problem
- Each node has a broadcast key for broadcasting to its neighbors: most efficient solution

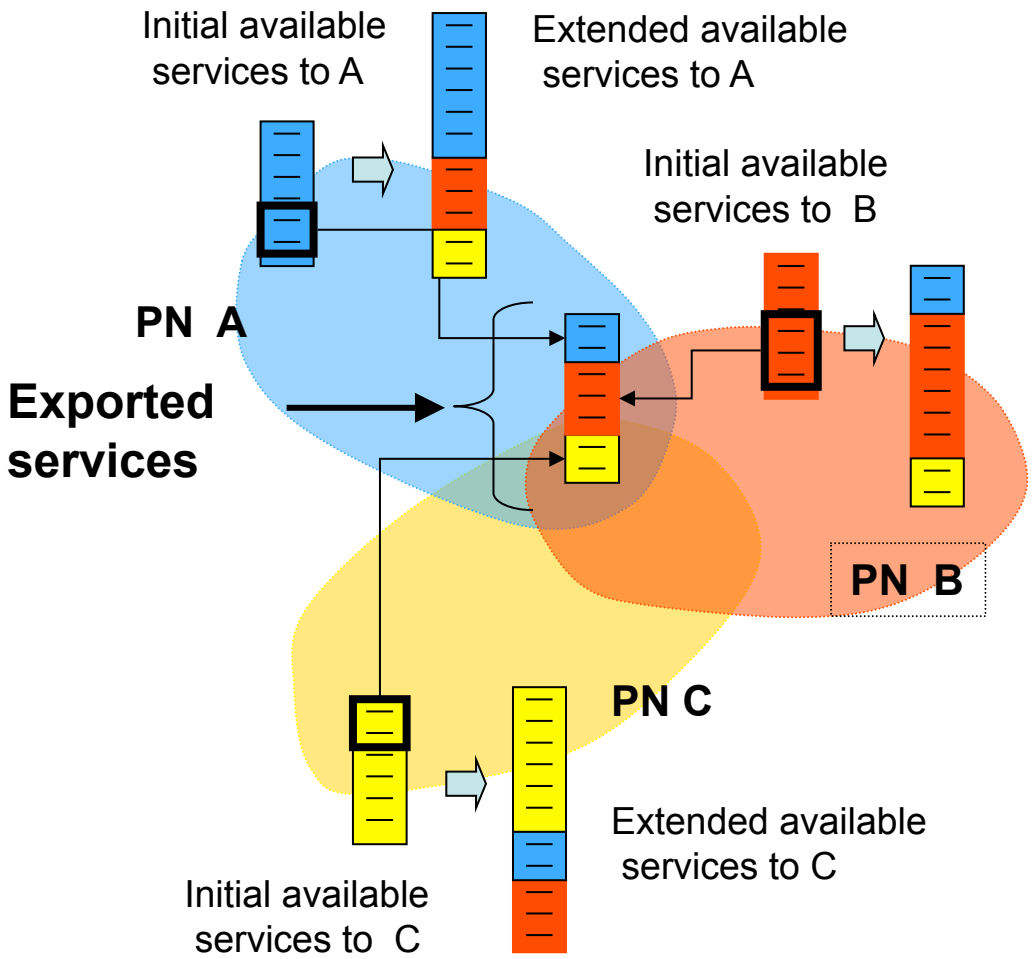
Secure inter-cluster communication

- Gateways nodes are responsible for securing inter-cluster communication
- IPSec tunnels
- Algorithm for key establishment similar to the second phase of the CPFP
  - Gateway nodes exchange PNCA certificates
  - After successful authentication session keys are generated

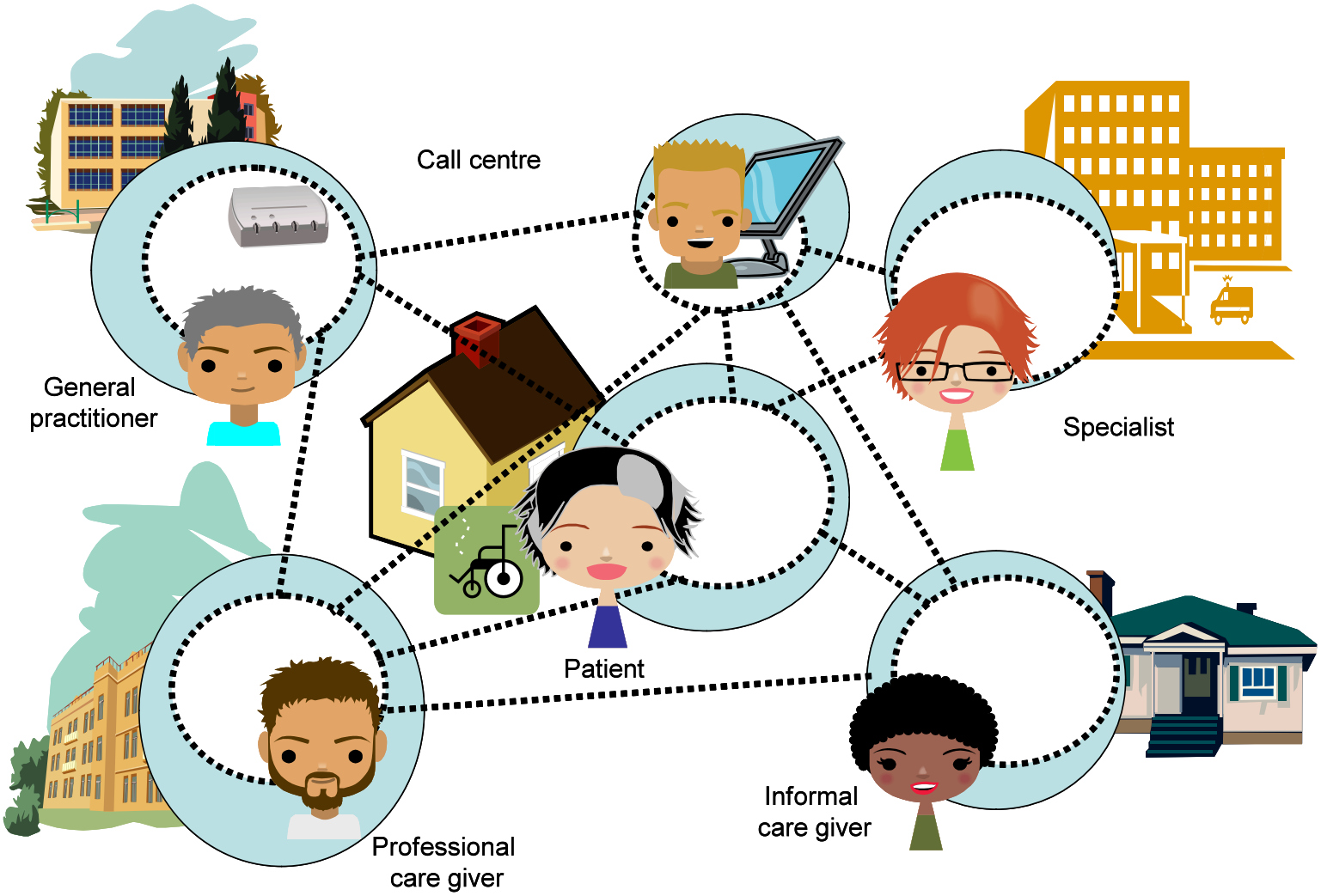
PN Federation (Fednets)

A cooperation of independent PNs with the purpose of achieving a specific common goal

PN federation concept



PN Federation for Health



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pucc
P2P Universal Computing Consortium

Healthcare Monitoring System
- For a long and healthy life -

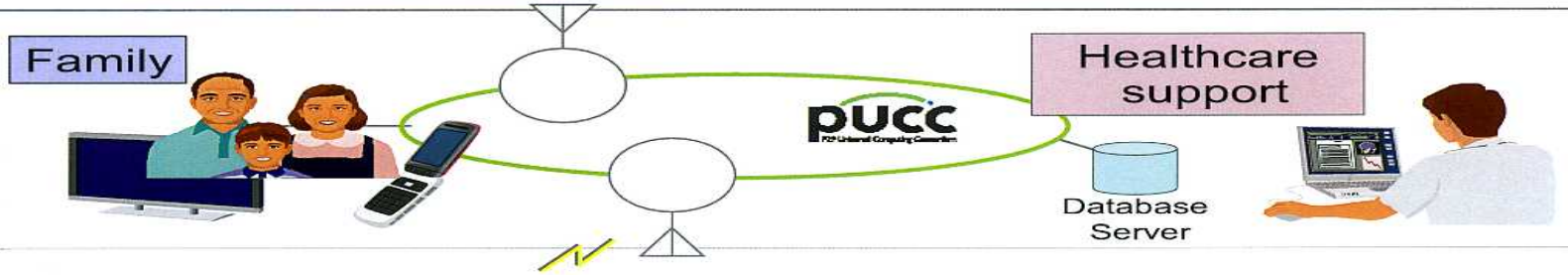
Healthcare monitoring wristband device

Acceleration

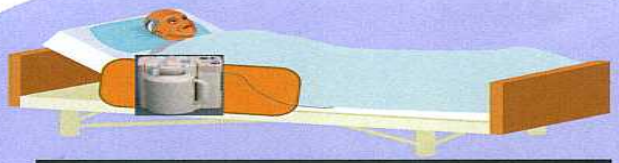
Body temperature

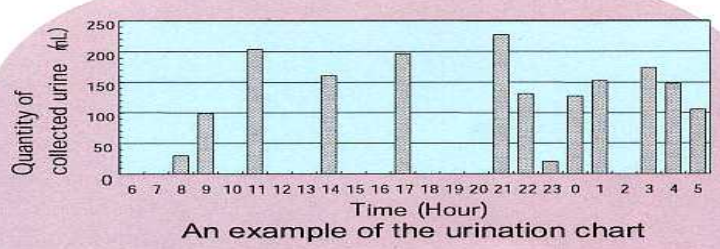
Exercise Volume
Daily rhythm

- Monitors the user regularly and gathers data.
- Transfers gathered data to healthcare supporters to control user's daily healthcare.



Automatic urine collection system

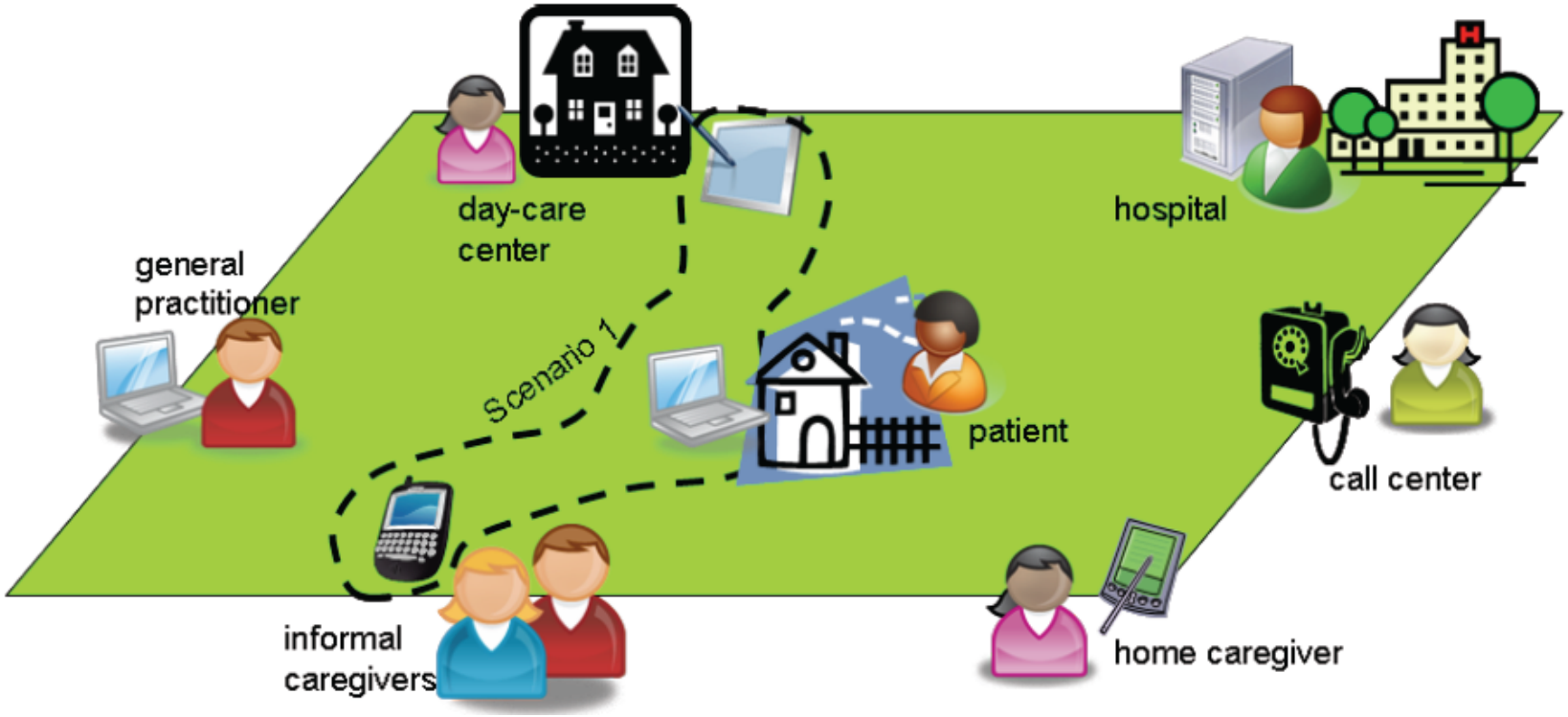




An example of the urination chart

- Creates a urination chart.
- Allows nurses to provide high-quality healthcare such as knowing the amount of water to give and when to take patients to the bathroom.

ECMA Homecare Scenario

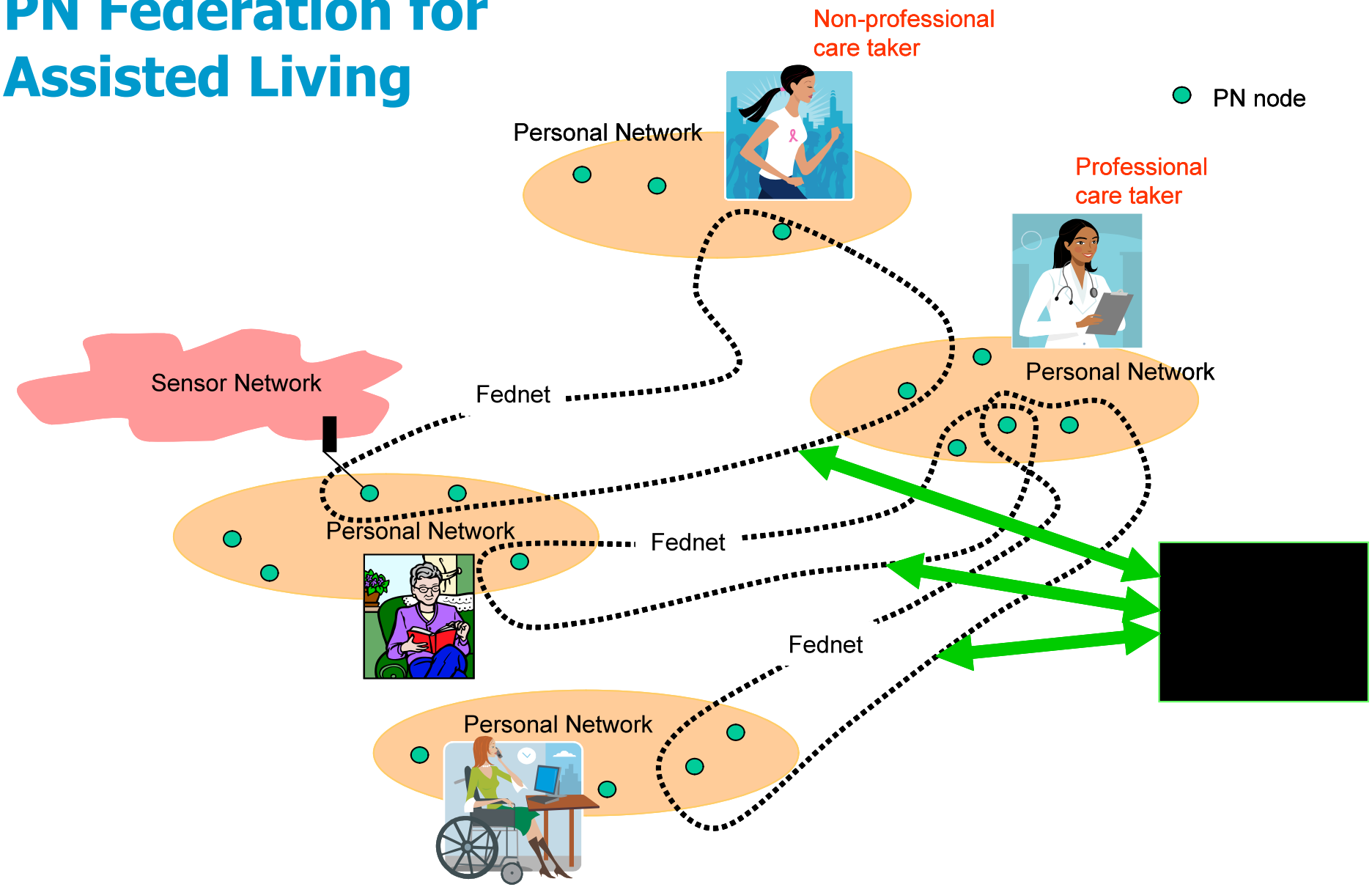


Ecma TC32 PN&F Editing Group, "Personal Networks and their Federations," *Ecma Technical Report*, 2009.
http://www.ecma-international.org/memento/TC32-PNF-M.htm

Rehabilitation of Stroke Patients

- PN consisting of sensing, actuating and remote monitoring systems
- Involvement of additional sensing systems not intended for medical applications (e.g., smart phone sensors)
- Involvement of rehabilitation-professionals through Federations
- Dynamic adaptation to phases of rehabilitation and to context

PN Federation for Assisted Living



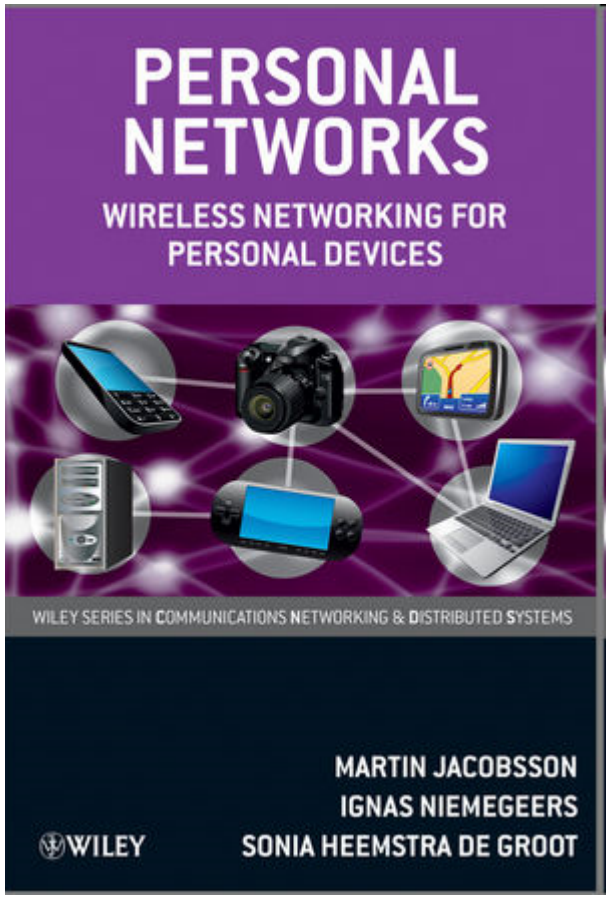
Further reading

Personal Networks: Wireless Networking for Personal Devices

Martin Jacobsson
Ignas Niemegeers
Sonia Heemstra de Groot

Wiley Series on Communications, Networking and Distributed Systems

Wiley, 2010



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