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Ad Hoc Network Virtualization
(Virtual Private Ad Hoc Networks)

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Current and Future Evolution

- 4G: Evolution towards a "network of networks"
  > integration of different technologies:
    - Cellular: > 1 billion subscribers, migration to UMTS
    - WLAN/WPAN/WBAN: lower cost, higher efficiency, different radio technologies
    - Satellite: successful for broadcasting
    - Fixed: higher bandwidth, lower cost, VoIP
    - Ad hoc and Mesh Networks: infrastructureless, self-organizing
  > Some characteristics: IP-based, broadband, mobility support, heterogeneity

Consequences?
Consequences - observations

- Connectivity anywhere, at anytime and from any device
- Bigger and bigger
  - In terms of the user base
  - In terms of the number of devices
  - In terms of the number of available services and data
  - In terms of the number of available networks

Bigger is better?
- User will be overwhelmed: what, when and how to choose?
- More security risks
- Current focus is mainly on connectivity
- How to manage all this?

What are the user's communication needs?
- Communication often takes place within a limited context or scope, e.g.
  - Work related communication: projects, customers, students...
  - Personal communication: friends, family, hobbies...
- And thus involves only a limited subset of devices
  - Dynamic subset
  - Mobile subset
  - Distributed subset

This aspect of communication is not reflected in current and future communication networks
Network virtualization:
- 4G all-IP network = carrier that provides end-to-end connectivity
- On top: multiple virtual networks that logically structure the network and its services into small secure communities

Ad hoc
- Formed when needed according to user needs and context
- Self-organizing and self-maintaining
- Dealing with distributed, mobile and dynamic characteristics

= VPAN (Virtual Private Ad Hoc Network)

Definition:
- A secure and self-organizing virtual overlay network of distributed nodes
- Deploying ad hoc network techniques and private addressing to enable connectivity
- Secure: both in terms of networking and applications and services

VPAN example

Communication is confined within secure environment provided by the overlay
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Applications of VPAN concept

- Rescue people (police men, fire fighters...) organized in teams
- Soldiers divided in separated military units, potentially hierarchically organized
- Overlay network between collaborating people: within a department, between people at a construction site, monitoring networks, augmented reality support
- Virtual classrooms, project collaborations
- Multi-user games
- Closed P2P communities
- Overlay of all your personal devices
- Distributed virtual desktop (i.e., access your data from any device)
- Cab network, surveillance systems, tourist information

The VPAN concept should support all these applications in a generic way

Challenges

- VPAN membership configuration and management
  - VPAN creation and definition of membership policies
  - Secure storage of membership information
  - Member addition, removal, banishment
  - Member authentication
  - Provider/operator support?
- VPAN formation and maintenance
  - Self-organization
  - Member discovery
  - Addressing and routing
  - Member mobility management
- Protocol stack development
  - Support of multiple VPANs in one device (multiple dynamic stacks with common management platform)
  - Device support (e.g., small devices like mobile phones)
Challenges (2)

- Security
  - Member authentication
  - Key establishment
  - Encryption, tunneling...

- Application middleware
  - Not only limit VPAN access to members
  - Also provide access right enforcement on applications and services
    - E.g.: project files can only be access through the VPAN established with the project team members
    - Software support needed (for interfacing with VPAN)
    - Additional level of security (next to network level security provided by the overlay)

- Generic network platform

- Operate on top of heterogeneous networks
- ...

Limitations of current technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Limitations</th>
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<tbody>
<tr>
<td>VLAN</td>
<td>Layer 2 solution: switching, no routing or private addressing</td>
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<tr>
<td></td>
<td>No application support</td>
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<td></td>
<td>No security</td>
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<tr>
<td>VPN/Dynamic VPW</td>
<td>Mainly static (predefined endpoints)</td>
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<td>No mobility management through dynamic tunneling</td>
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<td>Security only between two endpoints</td>
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<td>No application support</td>
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<tr>
<td>P2P Overlay</td>
<td>Application layer solution that runs on top of the existing IP infrastructure</td>
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<td>Limited flexibility as too tightly coupled with a specific application: not generic enough</td>
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<td>VIOLINK</td>
<td>Distributed overlay of virtual machines: each virtual machine can run its own applications</td>
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<td>Central management</td>
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<td>No mobility management</td>
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<td>Developed with grid computing in mind</td>
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**Conclusions**

- **Evolution towards all-IP 4G networks**
  - Enabler of connectivity anywhere, at anytime and from any device
  - Provides the connectivity, but is logically (from a user perspective) unstructured
  - Existing technologies do not support our vision of logical structuring

- **Migration towards ad hoc network virtualization (VPAN)**
  - Virtual IP overlays established on top of physical IP infrastructure
  - Using ad hoc networking techniques
  - Communication confined within member nodes
  - ... and within applications and services that have sufficient access rights

- **Transparent user-friendly communication platform that benefits from connectivity offered by the underlying base network**

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**Questions?**

Thank you