Integrated Communication Systems

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Future Internet a Service oriented Approach

SONATE

(Service-oriented Network Architecture)

7th Würzburg Workshop on IP: Joint EuroFGI and ITG Workshop on "Visions of Future Generation Networks" (EuroView2007)

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1.

What we are talking about

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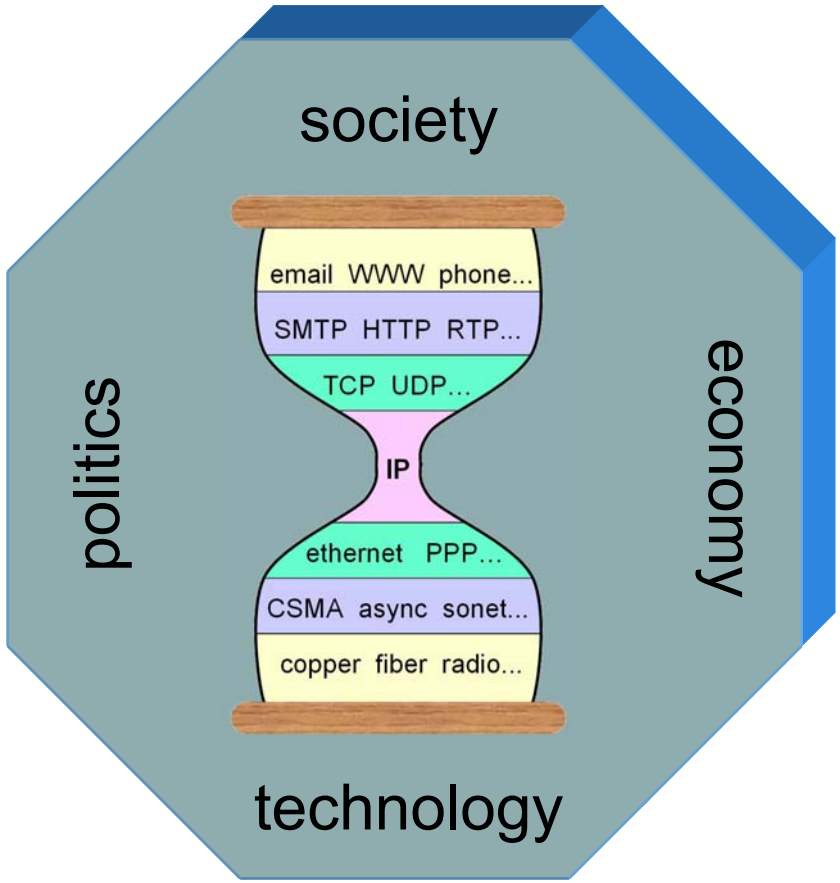
What we are talking about?



- I do not talk about:
  - Society
  - Technology
  - Economy
  - Politics

  } **STEP**
- But: Architecture and how it can evolve a new “inter-networking” Paradigm
  - At least as good as todays solution
  - Replace the traditional protocol layering paradigm with a more general model

Architecture

- Generic definition of the term architecture:
  - The art and science of designing structures
- In computer science, architecture is the (ANSI/IEEE Std. 1471-2000):
  - fundamental organization of a system
  - relationship of components (to each other and environment)
  - design and evolution principles
- Why is architecture a challenge?
- Question for dynamic software systems?
  - Which and how much system specific information (functionality, environment, usage, ...) should be considered by an architecture ?
    - too little information cause unstructured or even chaotic systems
    - too much information cause inflexible systems

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Architecture of the current Internet

- Fundamental organization
  - Layered Structure
  - One or more parallel protocols per layer
  - Functionality per layer is defined and fixed by a model (OSI or TCP/IP).
  - Location of functionality (end-system or network) motivated by the “end-to-end argument”
- Relationship of components
  - Each layer uses services of lower layers and offers another service to the upper layer
  - Interfaces between layers are not defined, only few common interfaces exist, most prominent:
    - The (Berkley) Socket Interface (access to layer 4)
    - NDIS Network Device Interface Specification (access to layer 2)
  - Interface between protocols of the same layer are not defined (IP ↔ ARP, IP ↔ Routing-Protocols)
- Design and evolution principles
  - Overall
    - It should be possible to redesign a layer and its protocols without having to change the adjacent layers (OSI specification)
      - But IPv6 requires a new TCP implementation
  - Per layer
    - Use only services of lower layers, i.e. mechanisms of lower layers are transparent
      - But TCP/UDP include IP-pseudo-header in CRC
  - Per protocol
    - Options
    - Version numbers
    - Some bits for “future use”

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Basic assumptions … but

- The end-to-end principle
  - Do not trust the network
    → implement several functionalities in end-systems
  - There are many miss behaving / malicious end-systems (users)
    → today the network can not trust the end-systems
- Layered Architecture
  - Transparency of lower layers → simplifies design
  - Today we have cross layer design – security balconies- …
- Keep the network simple
  - Stateless IP in the core → robustness
  - today we have additional mechanisms for QoS / MPLS …
- Convergence is based on IP
  - Widespread and mature technology
    → available within many devices (from PDA to HPC)
  - Widespread technology with low potential for evolution
    → mobility, sensor networks, …

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Problems of the current Internet

- Low degree of flexibility
  - Short term:
    adaptivity and adaptability according to environmental conditions and user requirements
    - no negotiation of capabilities
    - Inflexible protocols
  - Long term:
    enhance and exchange functionality
    - Exchange nearly impossible (e.g. IPv4 -> IPv6)
    - Enhancements in narrow bounds is possible
- Typical solution today:
  - Cross-layer optimization:
    improve adaptivity / adaptability
    - Optimize several protocols
    - Violate layered structure
  - Overlay networks:
    new mechanisms
    - Rebuild functionality of "lower layers“ at “higher layers”
    - Enables (new) functionality for few applications only
      - How many overlays will be required?

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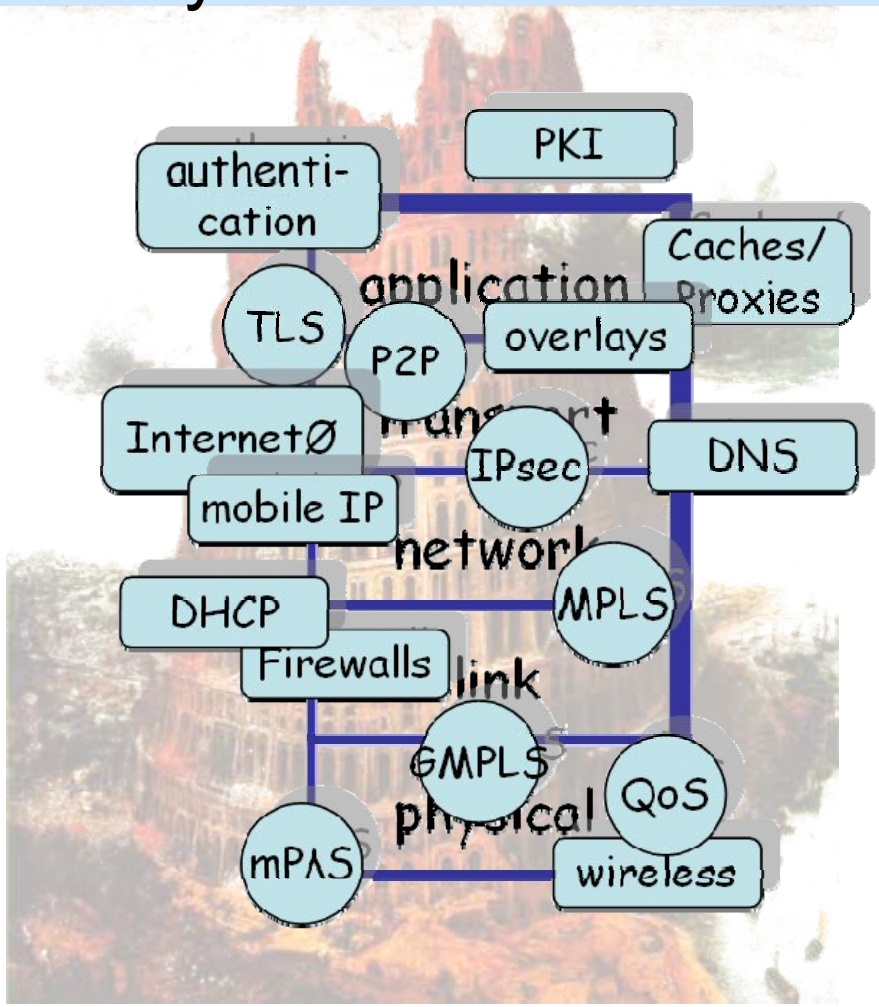
Architecture of the current Internet summary

- Original architecture is violated
  - Middleboxes (NAT, caches/proxies,…)
  - Intermediate layers (TLS, IPsec, MPLS, ...)
  - Specialized network domains (areas with specific QoS or security properties)
- Increasing interdependencies hinder innovation
  - Hard to integrate new mechanisms
  - QoS / CoS
  - Mobility
  - Security / Authentication
- Complexity is still rising …



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but …

There are fundamental issues with the current architecture and many of its mechanisms that cannot be fixed incrementally with additional engineering workarounds.

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Related Work

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Related Work 1

- The most interesting clean slate approaches which are related to the work presented here can be seen in the
  - role-based approach (RBA) conducted in the NewArch project;
  - and the SILO approach introduced by Dutta et. al.;
  - And more general the Clean-Slate project at Stanford.
- The RBA represents a non-layered architecture organizing communication in functional units referred to as “roles”.
  - Roles are not hierarchically organized, and thus may interact in many different ways;
  - as a result, the metadata in the packet header corresponding to different roles form a “heap” not a “stack”, and may be accessed and modified in any order.
  - The main motivation for RBA was to address the frequent layer violations that occur in the current Internet architecture

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Related Work 2

- The SILO approach also introduces a non-layered design
  - It is based on silos of services assembled on demand and specific to an application and network environment.
  - it offers a more flexible header structure than the RBA approach
  - The overall goal of the SILO architecture is to facilitate “cross-layer” interactions
- Some earlier work in the area of micro protocol architectures investigated also more flexible communication frameworks.
- SONATE, RBA and SILO are similar approaches; all three avoid layering and aim to define a highly flexible architecture.
  - The main motivation for RBA and SILO was to address the frequent layer violations that occur in the current Internet architecture. Our approach is a more holistic one triggered by service-oriented architectures in the application domain.

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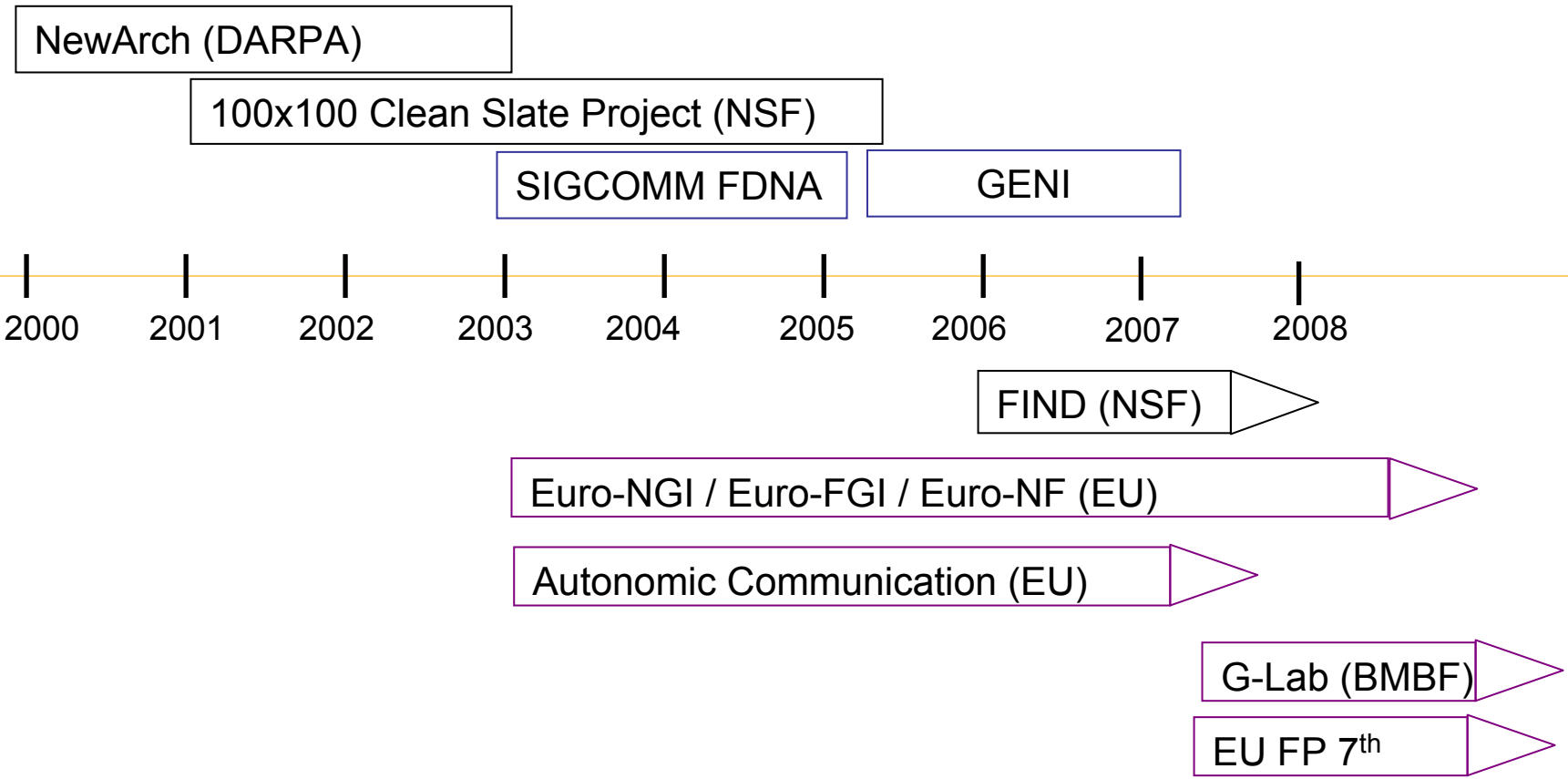
Related Work 3



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Service Approach for the Future Internet

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Service Approach for the Future Internet

- Basic Idea:
  - A communication system made of loosely coupled services
    → avoid implicit premises as much as possible
  - Apply SOA principles to communication systems (requires new techniques)

- Define explicit interfaces and interaction between elements of the architecture
  - Dependencies to each other

- Explicitly refer to required/offered functionality and data structures
  - Enables change of functionality and data structures and thus provides higher degree of flexibility

The term “Service” 1

- A definition from business economics:

Service is a customer-oriented result. This result is produced when an organization performs activities that are oriented towards meeting customer needs and expectations. [ISO 9000]

  - A service is a result (or benefit) for a customer
  - A service involves activities
  - A service involves two parties: provider and customer (which have to communicate somehow)
- How to describe a service ?
  - By action: can be very precise but requires specific knowledge
  - By what’s communicated: interface must be defined nonetheless but these often lack semantic
  - By benefit: is independent of activity and thus fosters loose coupling, but requires an expert to find an appropriate provider

The term “Service” 2

- A unit of work done by a service provider to achieve desired end results for a service consumer. The results of a service are usually the change of state for the consumer but can also be a change of state for the provider or for both

- Benefit: Loose coupling between the participating software agents, enabled by:
  - A small set of **simple and ubiquitous interfaces.**
  - **Descriptive** messages constrained by an extensible schema delivered through the interfaces. None, or only minimal, system behavior is prescribed by messages.
  - **Extensibility**
  - **Service discovery**

- Focus on exposing business functions, not technology

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Lessons learned from SoA 1

- 1. *Use self-contained services and data*.
  - This means to find appropriate granularity of services and data.
- 2. *Use explicit descriptions instead of implicit assumptions* (fostering loosely coupled services).
  - The current Internet is based on several "well known" protocols.
    - But presupposing protocols (i.e. rules and formats) implicitly lay down several technical details which are hard to change afterwards.
  - As implicit assumptions raise the grade of coupling, we propose to use explicit descriptions where ever possible:
    - a) explicitly describe required services, e.g. "forwarding of data", "reliable transmission" or "flow control";
    - b) explicitly describe types of data.

Lessons learned from SoA 2

- 3. *Use well defined interfaces between services* (fostering loosely coupled services).
  - Each service must have a well defined interface, hiding its internal mechanisms and data structures.
  - Protocols are the building blocks of the current Internet.
- But interfaces between different protocols – if they exist at all – do not hide protocol mechanisms. For example the BSD Socket Interface does not hide which transport or network protocols are used, this hampers exchanging protocols because adjacent layers also require adaptation.

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Services Categories 1

- Infrastructural services:
  - Services on the lowest level represent the provisioning of resources
    - Like Ethernet, Frame-Relay or ATM offer infrastructural services, but also P2P overlay networks, ad-hoc networks, or even sensor networks offer such services.
- Basic communication services:
  - This category offers the transport of data between two or more entities.
    - Therefore functionalities like switching, routing, and signalling must be implemented. Each of them, may be individual services. Today protocols like TCP/IP, ATM, ISDN and even H.323 and SIP implement basic communication services among other things.

Services Categories 2

- Extended communication services:
  - Examples for these are privacy, security, availability, robustness, accounting, and quality-of-service,
  - The necessity of these services depends on the demands of consumers and providers.
- Intermediary services:
  - Services that help in finding appropriate services.
  - Bootstraping systems
- Context adaptive and intelligent user services:
  - These are types of services providing users the ability to access the services they need, anywhere and from any device.

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Services Categories 3

- Information services:
  - Services that provide (personalised) information, for instance by comparing, classifying, or otherwise adding value to separate information sources.
- Mangement services:
  - All kinds of services have to be managed. This covers tasks like service deployment, monitoring, (self-) configuration, and (self-)optimization.

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Examples of Services 1

- Error handling
  - Error detection
    - CRC, Hash, ...
  - Error notification
  - Error recovery
    Retransmission or FEC
- Identifier
  - Identify an endpoint
  - Identify a location
  - Identify a process
  - Identify a user
- Multiplexing
- Fragmentation/Assembly
  - Fragmentation
  - Segmentation
  - Blocking
- Connection / flow setup
  - Implicit
  - 3-way handshake (e.g. TCP)
  - 4-way handshake (e.g. SCTP)
  - Dynamic label distribution (e.g. MPLS/GMPLS)
  - Halfclose
- Address resolution
  - ARP, DNS
- Routing / forwarding
  - Use local routing tables, DHT
- Flow Control
  - with respect to destination
  - Congestion control, i.e. with respect to network
  - Rate control
- QoS / CoS
  - Classes & Aggregation
    - DiffServ
  - Signaling
    - RSVP
- Path management
  - Path-switching
  - Path monitoring
    - keep-alive, heartbeat
  - MTU Discovery
- Multicast
- AAA
  - Authentication
    - 802.1x, Radius, TACACS, Kerberos
  - Authorization
  - Accounting
- Encryption
  - Key Exchange
    - Diffie-Hellman, RSA
  - Cipher-Algorithm
    - DES, 3DES, AES
- Real Time support
  - Content identification
  - Source identification
  - Start / Stop marker
  - Time + Sequence number
- Communication patterns
  - Request / Reply
  - Message Passing
  - Message Queuing
  - Publish / Subscribe
  - Media Streaming
  - File transfer

1. *This list is not intended to be complete*
2. *The protocols mentioned are not services by themselves, they are only examples for mechanisms*

Used by / required for TCP/IP

Examples of Services 2

- Loop detection and elimination
  - STP, MSTP, RSTP
- Trunking
- Virtual path / tunneling
  - MPLS/GMPLS
- VLAN tagging
- Load balancing
- Routing / determine topology
  - IS-IS, OSPF, IGRP, RIP
  - BGP
- Monitor infrastructure
  - Load
  - Error rates
  - Signal strength (wireless)
  - Availability
- Traffic engineering
- Network Management
  - Get / Set (e.g. SNMP)
  - XML based (e.g. netconf)
  - Provide configuration data
    - DHCP, TFTP
- Capability negotiation
- Network admission control
  - by user
  - by device / device configuration
- Network protection
  - Firewalls
  - Intrusion Detection
- Resilience
  - Path/Node failure
- Self-organization and self-management techniques

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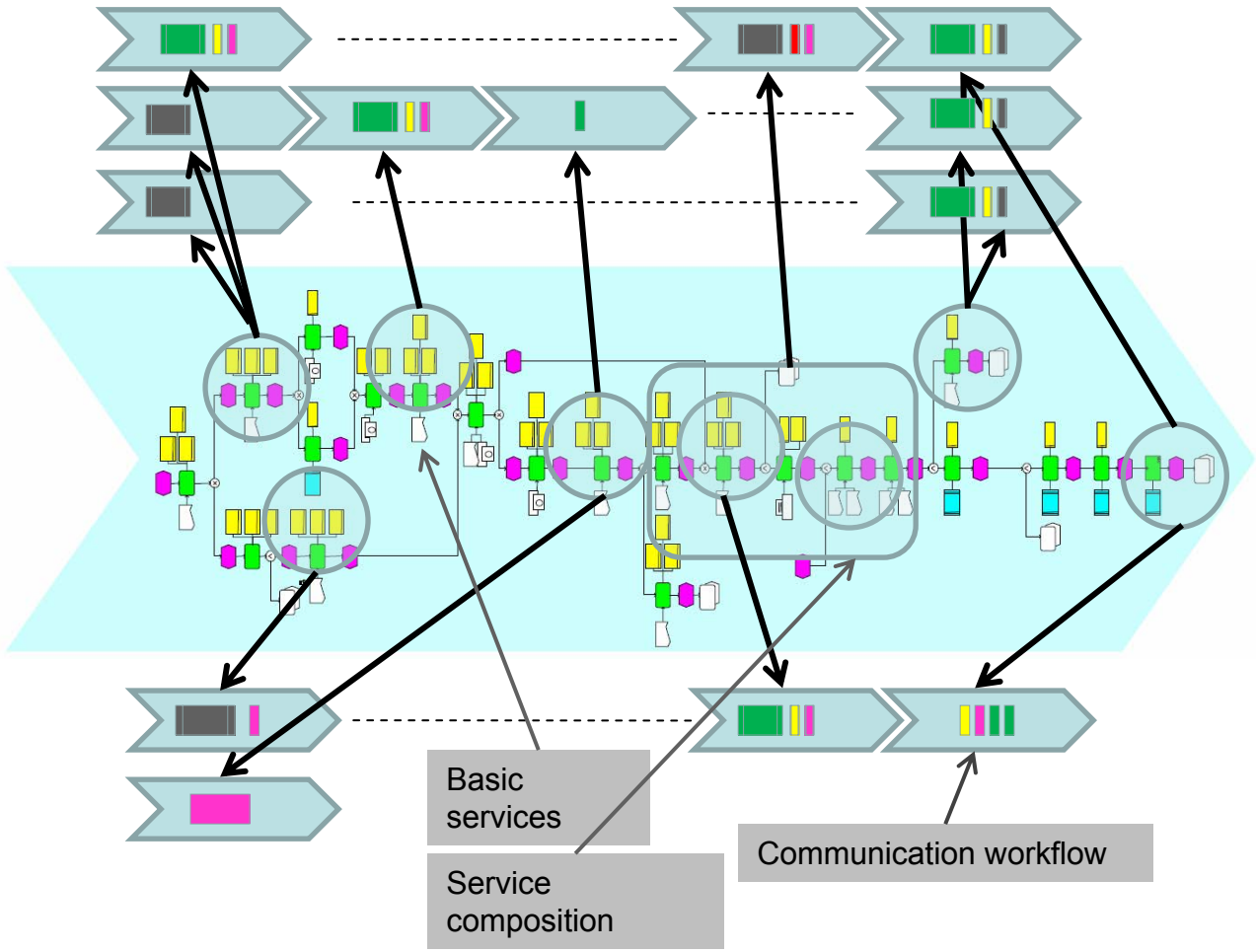
Service Approach for the Future Internet



Decomposing protocols into a set of reusable service elements that can be recomposed in different ways depending on application and network properties

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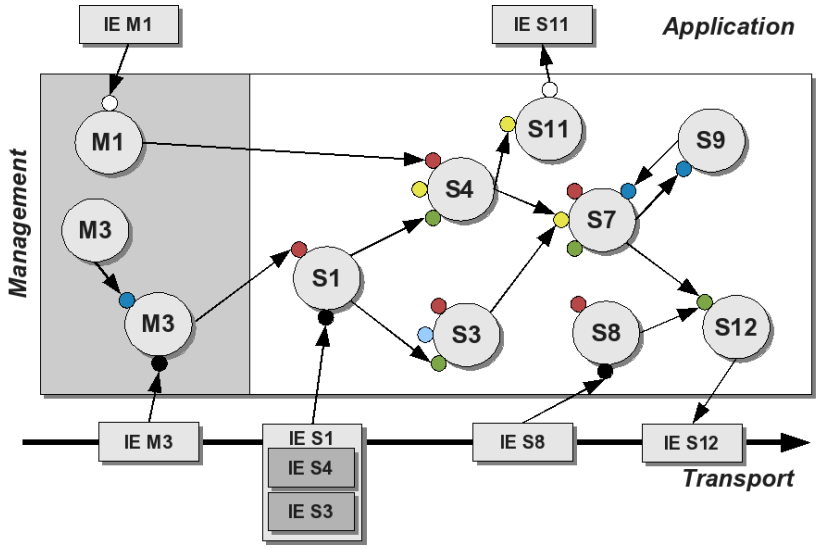
Illustration of the Services Concept

- Metadata increase flexibility
  - Explicit references to services
    - Simplifies provision of new services
  - Explicit descriptions of data types
    - Simplifies extensions of mechanisms (add optional data)
    - Enables alternative mechanisms (add alternative data)
- Services have well defined interfaces
  - Enable exchange of service implementations
- Services are fine granular
  - Similar to micro protocols
- Similar to “role based architecture” approach but:
  - Roles can be exchanged/replaced, but it is not possible to extend roles (e.g. add optional data)
  - Separates application payload from protocol header, i.e. one role can not contain other sub-roles.



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The Service Approach 1

- Avoid complex protocols
  - There is no need to bundle functionality that might be used independent of each other
  - Protocol decomposition to micro protocol is not new, e.g.
    - Dynamic Network Architecture (O'Malley & Perterson)
    - Dynamic Configuration of Light-Weight Protocols (Plagemann, Plattner, Vogt, Walter)
    - Componentized Transport Protocols (Condie et al.)
    - …
- The service approach is more general
  - Replacing ***implicit assumptions*** by ***explicit references*** does not reduce functionality

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The Service Approach 2

- Avoid to presuppose where some functionality is placed (end-system, network or network domain)
  - The end-to-end argument postulates that some functionality can only be implemented in end systems. But is the location of a functionality a principle that never changes?
    - *Saltzer, Reed, and Clark mention an alternative to end-to-end implementation: The goal would be to reduce the probability of each of the individual threats to an acceptably small value. This was considered to be too uneconomical (1984) → is this true today and in future ?*
    - *Moors argues that the end-to-end argument is mainly derived from trust and not from technical issues → what is acceptable depends on requirements!*
    - *Typically reliability should be provided end-to-end, but interceptions of TCP connections by proxies are reality today. Who cares about the reduced reliability?*
  - The architecture should not presuppose where some functionality is located, because this may change (but an application may do so).
  - In consequence: a layered structure is no longer appropriate

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Architectural Issues

- Flexibility
  - in the long run no fixed set of mechanisms/protocols will fulfill all requirements and are appropriate in all environments
  - Consequence: the future Internet must be flexible according to the mechanisms used
- Scalability
  - The future Internet should be accessible for everybody, everywhere, every time and at every scale: Dimension , Capabilities of links, Capabilities/resources of nodes
- Application neutrality
  - Do not presuppose who will use the network and how
    - Note: the current Internet was originally developed for data exchange between computers only

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Conclusion and Summary

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What we have learned from Service Orientation

- Eight common principles
  - Reusability
  - Formal contract
  - Loose Coupling
  - Abstraction
  - Composability
  - Autonomy
  - Statelessness
  - Discoverability
- Demand and foster a new thinking (“think SOA”)
- SOA is not a fixed solution, it’s a process
- Services should be
  - Solution-agnostic
  - Entity-centric
  - Not task-centric
- Service composition enables
  - Flexibility
  - Evolution
  - Dependability
  - Individual workflows

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Advantage

- For users
  - Adaptivity / Adaptability to environment
    - optimized performance
  - Adaptivity / Adaptability to requirements
    - optimized qualitative properties (i.e. QoS)
  - Request services instead of mechanisms
    - Easy to use, because much less technical know-how required
  - Extendable set of mechanisms
    - Large toolbox of services available
- For providers
  - Extendable set of mechanisms
    - Add functionality needed locally (e.g. for traffic engineering, accounting, management, …)
    - Easy to deploy new services
  - Reduced dependencies between mechanisms
    - Improved robustness

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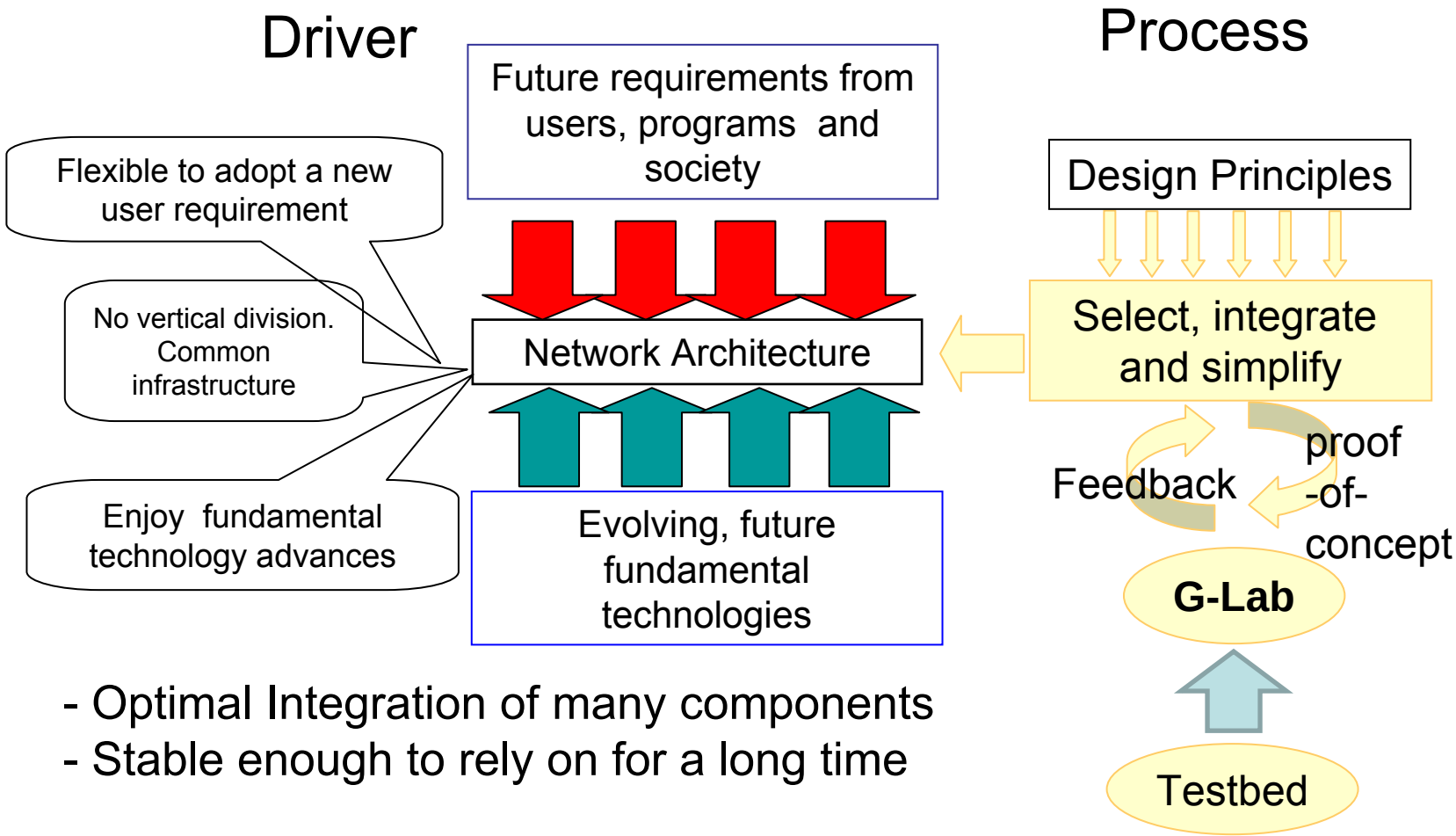
Conclusion



- Optimal Integration of many components
- Stable enough to rely on for a long time

Summary

- Tight coupling in the current Internet hinders adaptivity as well as evolution
- Goal: an architecture of loosely coupled elements (services) suitable for a future internet

Convergence

Should not be based on protocols

but on

Architecture

see also: http://www.future-internet.org

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