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Design issues in e-Infrastructures

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History of computing

- One application – one computer
- Many applications – computing infrastructure (computers (PC & servers), OS, network, printers, etc.)
- Ecologies of infrastructures – applications, computing platforms, Internet, ..
- => Information Infrastructures (or e-I, or cyber-I, or digital I, or)
- => Infrastructure Studies/Thinking (ex: Minimal invasive heart surgery, REF Impact Case Studies)

Ultra Large Scale Systems

Ultra-Large-Scale (ULS) systems (will push far beyond the size of today's systems and systems of systems by every measure:

- number of technological components of various kinds;
- number of people and organizations employing the system for different purposes;
- number of people and organizations involved in the development, maintenance and operations of the systems;
- amount of data stored, accessed, manipulated, and refined; and
- number of connections and interdependencies among the elements involved.

ULS systems will change everything; that ULS systems will necessarily be decentralized in a variety of ways, developed and used by a wide variety of stakeholders with conflicting needs, evolving continuously, and constructed from heterogeneous parts. Further, people will not just be users of a ULS system; they will be elements of the system. The acquisition of a ULS system will be simultaneous with its operation and will require new methods for control. These characteristics are emerging in today's systems of systems; in the near future they will dominate.

ULS systems presents challenges that are unlikely to be addressed adequately by incremental research within the established paradigm. Rather,

they require a broad new conception of both the nature of such systems and new ideas for how to develop them.

We will need to look at them differently, not just as systems or systems of systems, but as ***socio-technical ecosystems***.

http://www.sei.cmu.edu/uls/

Information Infrastructures - some examples

- General:
  - Internet & ***NORDUNet!!***
  - Facebook and iPhone & Android platforms ecologies,
  - Cloud Computing Infrastructures
- IS portfolios (in large distributed orgs.)
  - Patient Record Systems, HIS portfolios
  - Oil, banking, ..
- Business sector IIs
  - Pan-European eGovernment Infrastructures
  - Finance: SWIFT, High frequency trading
  - Media/advertising
- Many failures – including
  - Human Genome Project II in the 90-ies
  - Connecting-for Health in UK: 12.9 billion UKP!!

From IS to II: A new paradigm

- From
  - Tool (individual)
  - System (closed)
  - Design (from scratch)
  - Designed, maintained, scrapped
  - Simple
  - Flexible
- To
  - Infrastructure (shared)
  - Network (open)
  - ***Installed base*** Cultivation
  - Last forever, evolving
  - **Complex!!!**
  - Big and heavy
  - Standards

Innovation and technological development

- Technological evolution:
  - Recombination, structural deepening, re-domaining: “Technology makes itself out of itself”
  - reconfiguration, cross-appropriation, articulation
- Innovation:
  - Exaptive bootstrapping

- II = shared, open, heterogeneous, evolving installed base

II life cycle

- Evolutionary processes
  - Emergence
  - Growth (adoption, scaling, innovation)
  - Crumbling
  - Restructuring

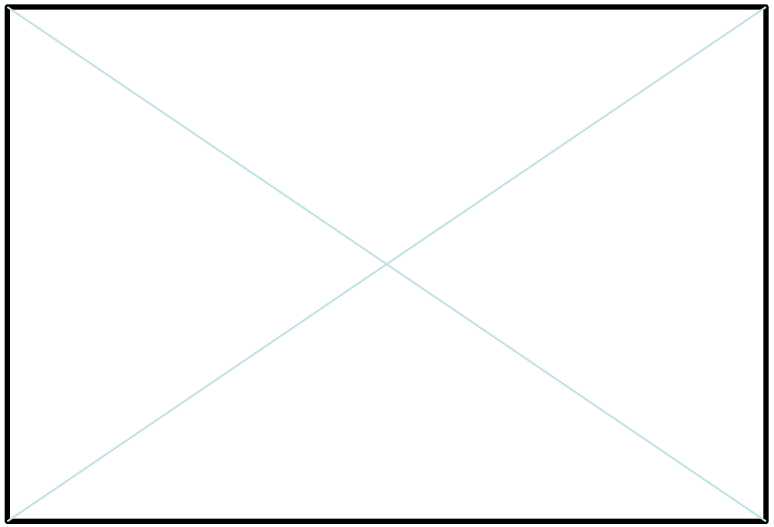
Design issues - challenges

- Issus
  - complexity – network effects
  - standards/standardization
  - Tensions
- “Tools”
  - Strategy (process)
  - Architecture
  - Governance regime

Alignment

Environmental dynamics

Process strategy



Architecture

Governance

Complexity Science

- Origin: Natural sciences, economic (history)
- Autonomous systems

- Emergent order (not designed)
- Non-linearity
- Network externalities (effects)
- Increasing returns/Attractor
- Path dependency
  1. Diffusion of standards, competition
  2. Change of standards: Backward compatibility
  3. Chain of events
- Lock-ins

- The 2 laws of historical evolution

- Installed base as complex evolving system

A self-reinforcing installed base

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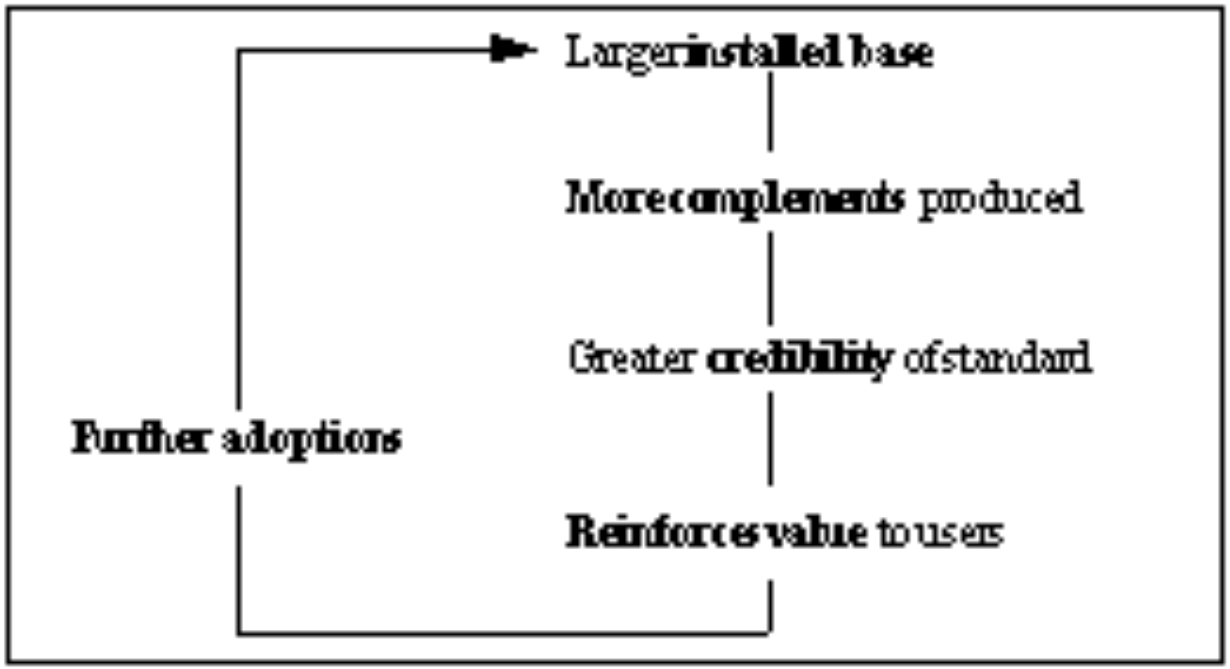


’Multidimensional’ critical mass

- Granovetter’s pedestrians: distribution of individual preferences.
- Diversity of users (motivation, knowledge, style, …)
- Heterogeneity of use areas and of technologies.
- Networks of networks

Dilemmas

- Take-off
- Lock-in

Standards and standardization

- The formal, (Telecom) model:
  - Specification driven, slow, “in crisis”
- De facto
- The Internet model:
  - Experimental, bottom-up but coordinated
  - «We rejects kings and tsars and voting - we believe in rough consensus and running code»

Architecture/governance – coping with tensions

Stability

- Integration
- Standardization
- Centralization
- Long term

- platform

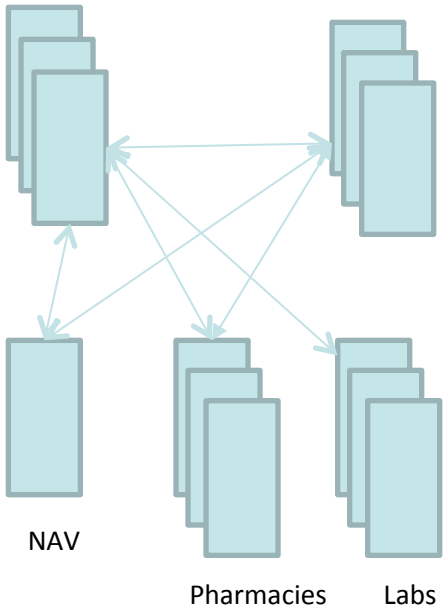
Change, innovation

- Modularization
- Variety/flexibility
- Decentralization
- Short term

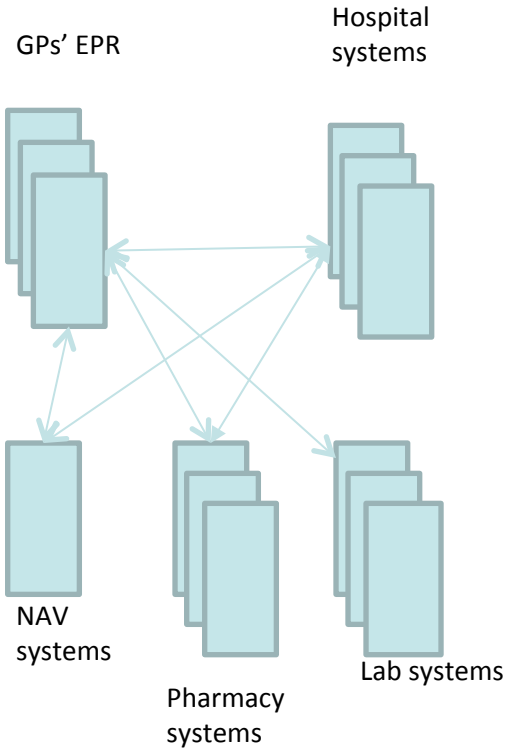
- apps

Architecture & the EDI Paradigm

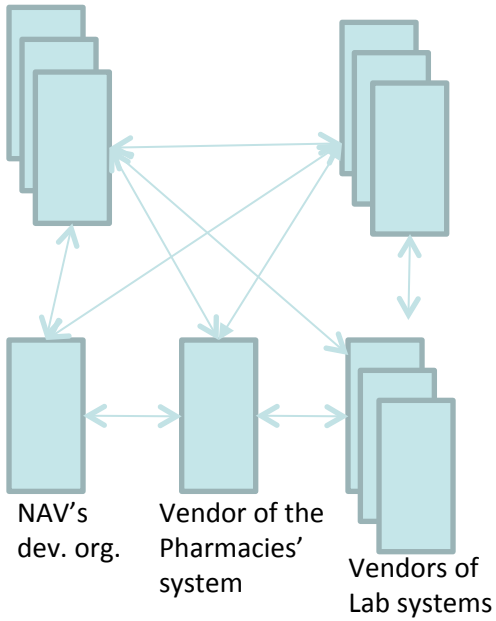
Information flow



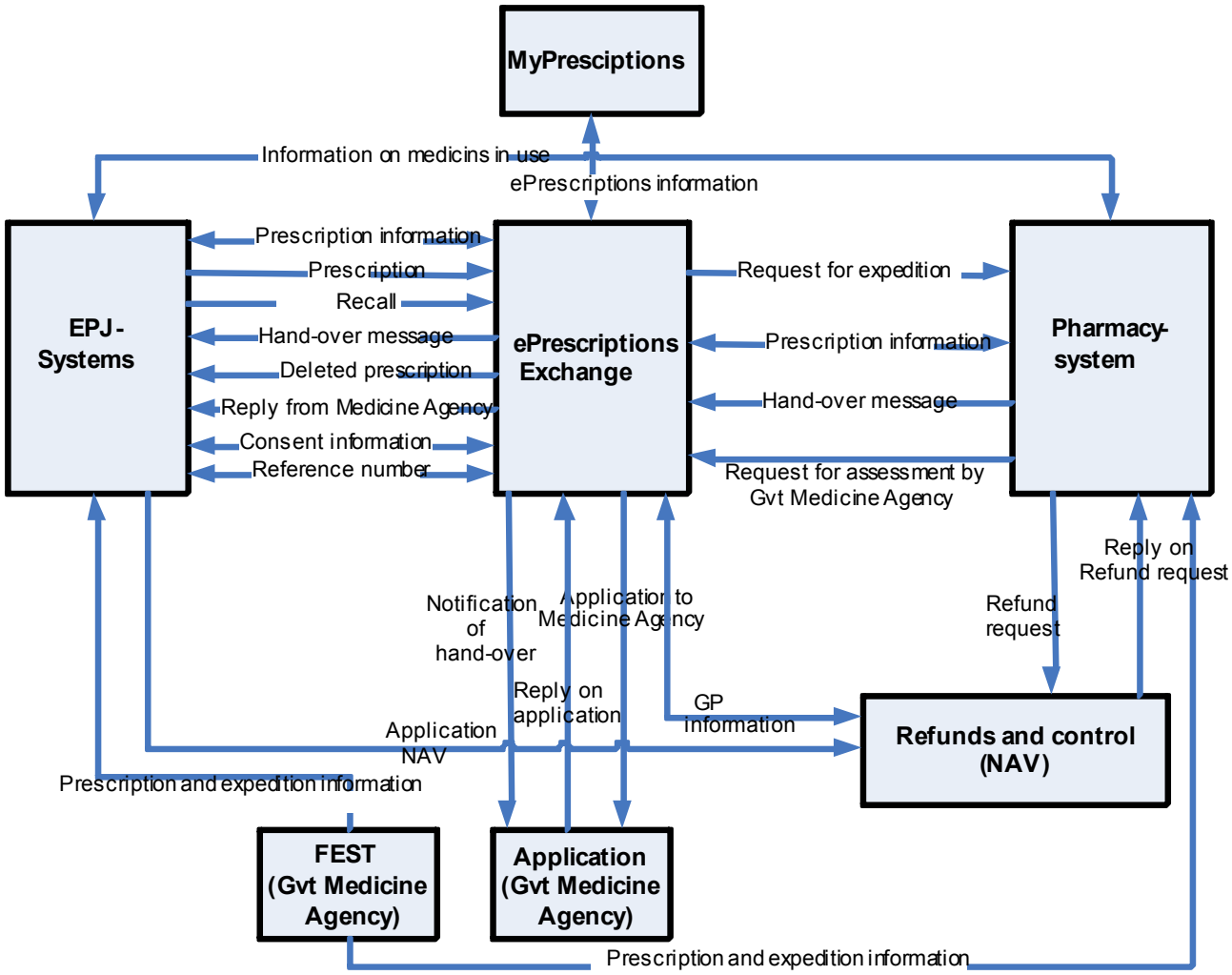
ICT architecture



Project organization



Architecture: ePrescription in Norway



Network Governance

- Goal-directed – serendipitous
- Brokered or shared governance
- Externally or participant
- Externally:
  - Mandated or voluntary
- Shared Governance
- Lead organization
- Network-administrative organization

Governance Forms	Trust	Number of participants	Goal consensus	Need for network level competences
Shared governance	High density	Few	High	Low
Lead organization	Low density, highly centralized	Moderate number	Moderately low	Moderate
Network administrative organization	Moderate density, NAO monitored by members	Moderate to many	Moderately high	High

Examples: Internet and telecom

	Internet	Telecom
Process strategy	Experiemntal, evolutionary, bottom-up	Specification driven, top-down, ”anticipatory standardization”
Architecture	Distributed ”End-2-end”	Centralized ”Intelligence in the centre”
Governance regime	Loosely coordinated network, open source, communication technology	Hierarchical, open standards + proprietary technology (patents)