

# CONVERGENCE OF MAN AND MACHINE PROCESSES IN THE EMERGING INTERNET

*From technology to economic and social benefits*

***INFOCOM 2006***



Prof. Imrich Chlamtac

[chlamtac@create-net.org](mailto:chlamtac@create-net.org)

[www.create-net.org](http://www.create-net.org)

## Outline

- Unified (communications) theory for solving digital divide and economic growth challenges can lead to increased shared wealth
- Autonomic communications as an intermediate step
- Life (sciences) turning unmanagable complexity into self managed evolution as basis for emerging communication/computing systems

# Global Challenges and Problems

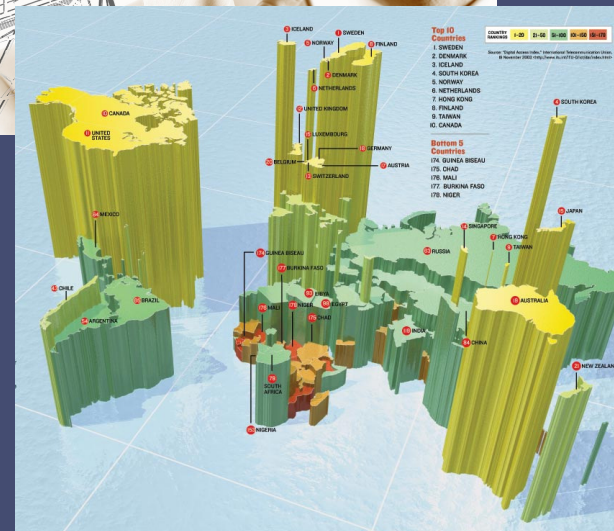
- Challenges

- Mankind over 6 billions, growing to 16, 26...
- Providing basic needs (education, transport...) and opportunities for all



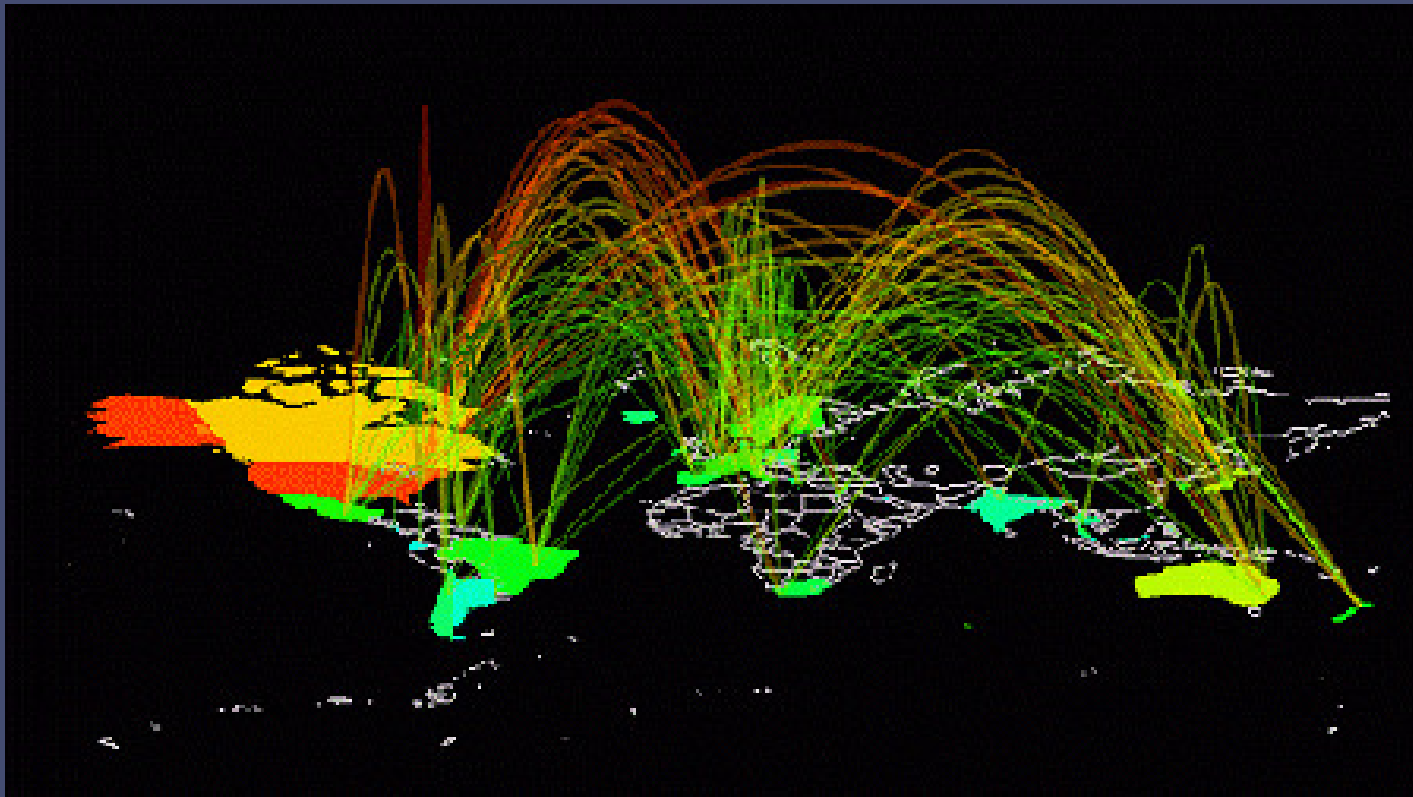
- Harnessing ICT

- To create individual wealth by
- Bridging the Digital Divide &
- Turning globalization into a positive phenomenon



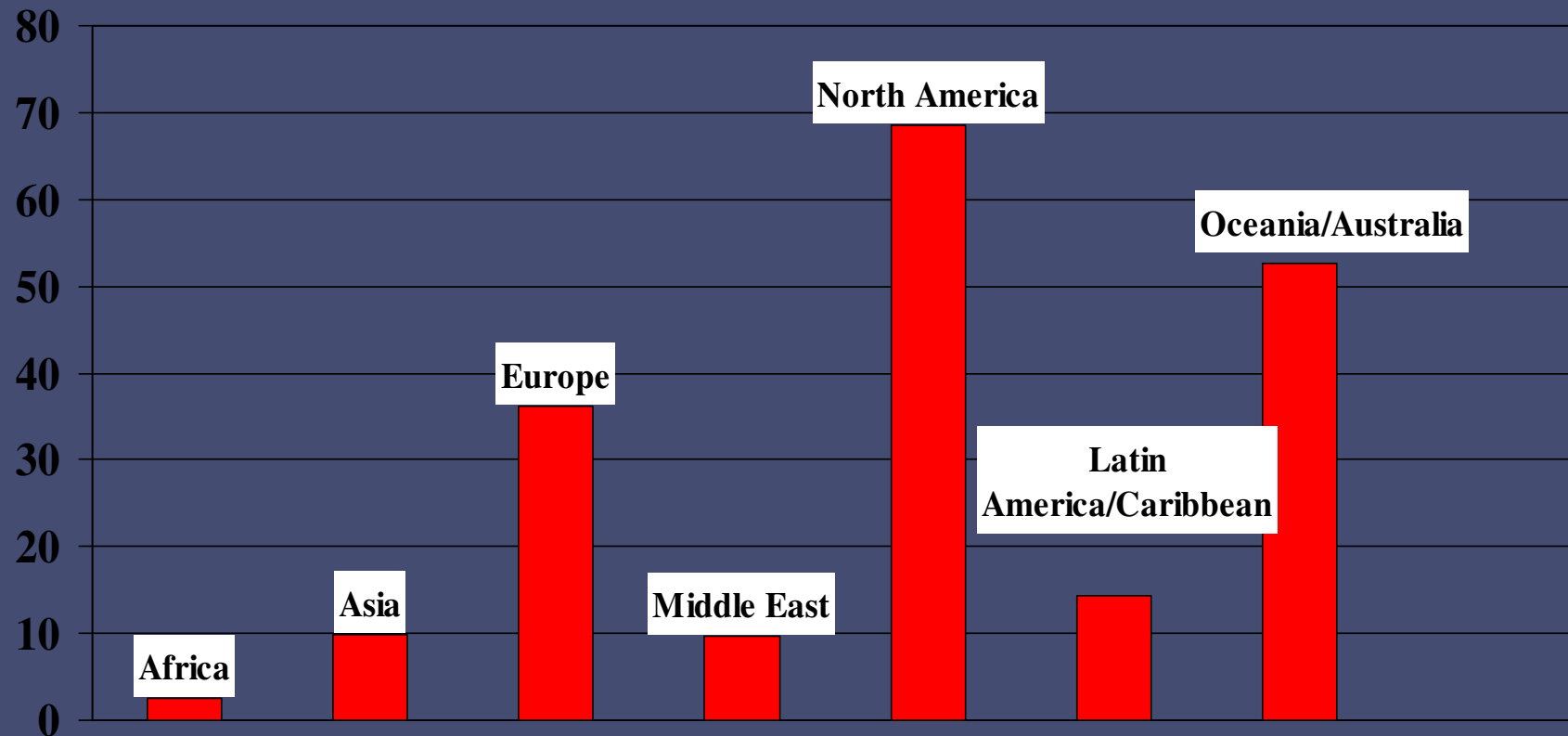
*Internet as commodity*

# Internet Connectivity



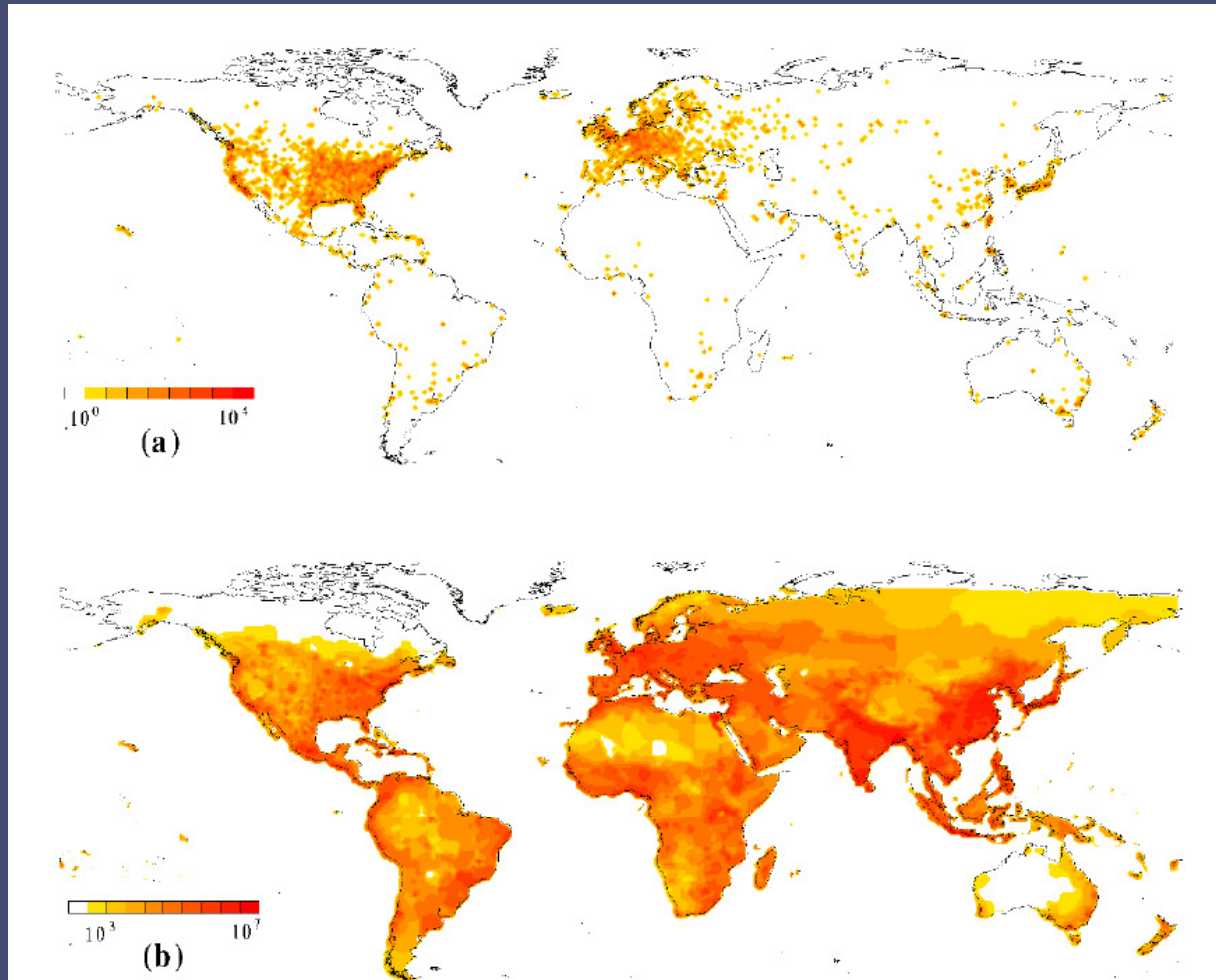
Source: Visual Insights

## Internet Penetration (2005)



The penetration of Internet is highly correlated with the advancement level of the underlying society

# Comparing Density of Routers and People



## Bridging the Digital Divide

*“In a fair society, all individuals would have equal opportunity to participate in, or benefit from, the use of computer resources regardless of race, sex, religion, age, disability, national origin, or other such similar factors.”*

*ACM Code of Ethics*

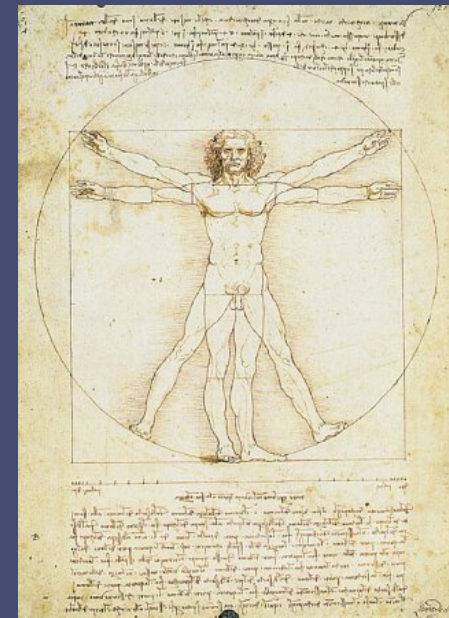
## In fact...The *Evolving* Digital Divide



A way to solve Digital Divide and Increase Growth in a Single Equation... To create and divide

...building user centric & autonomic technologies and services

As technology continues to evolve, paradoxically the digital divide continues to grow due to need for increased user expertise





## User-centric Internet

Turning Internet into a commodity for the basis of the [social] pyramid as a great hidden market (*The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits*, by C. K. Prahalad)

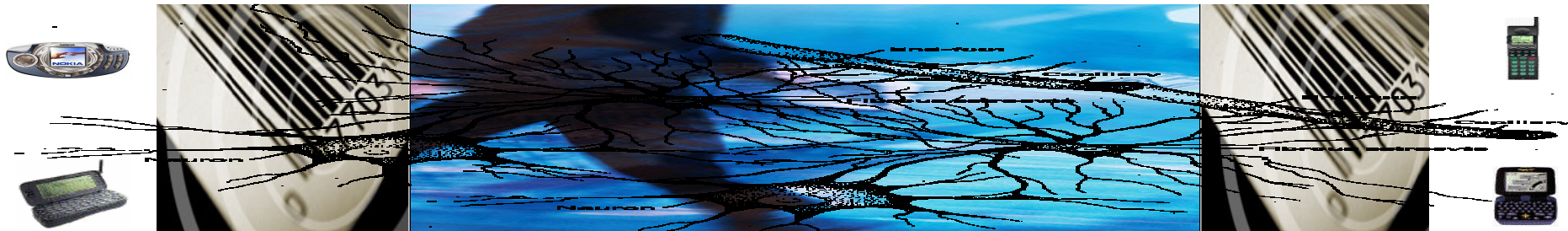
- Communications architectures: eliminate end-to-end complexity, resulting cost and provide scalability by autonomic communication  
substitute networks by user centered intelligent communication
- Services: put means and ends in the right order  
design communication systems around intelligent, user centered, services
- Usability: man machine interaction from one to five senses
- Security: overcome real and perceived barriers
- Communications Technologies: on demand bandwidth as commodity

## Communication Systems Today

- The emerging world is pervasive and strives to provide services which integrate people, environment and knowledge
- The supporting communication systems, including IP networks, are technology oriented rather than service oriented
- Social networks and information networks are divided and dissonant
- Emerging systems will have to be autonomic, scalable and adaptive, to respond to the social communication needs

# From Networking Technology Point of View

- The emerging XXI century scenario
  - large number of user mobile devices with growing computing / communications capabilities
  - billions of simple sensing/identifying devices enabling interaction with the environment
  - Managed and interconnected by 40+ year old Internet concepts



## Facing the Challenges

- The emerging Internet of billions of miniaturized devices will, from a networking point of view, face three key challenges:
  - *SCALING*: inherent barriers of any existing top down, end-to-end architecture
  - *COST*: of pervasive, mobile devices and their interconnection
  - *COMPLEXITY*: need for communication paradigms with linear complexity management

## Where Conventional Approaches Fail

- Observation: Current (Internet) network technology is not suitable for future pervasive environments

Fundamental problem in wireless networks (including mobile networks):

$$\lim_{n \rightarrow \infty} \frac{tpn(n)}{n} = 0$$

- $n$ : # nodes in network
- $tpn$ : throughput per node

– “One size fits all” protocol stack based on end-to-end TCP/IP

– Network management: difficult, not scalable, not fully automated

– Services: centralized approach, difficult to manage

scalability problem

cost problem

management problem

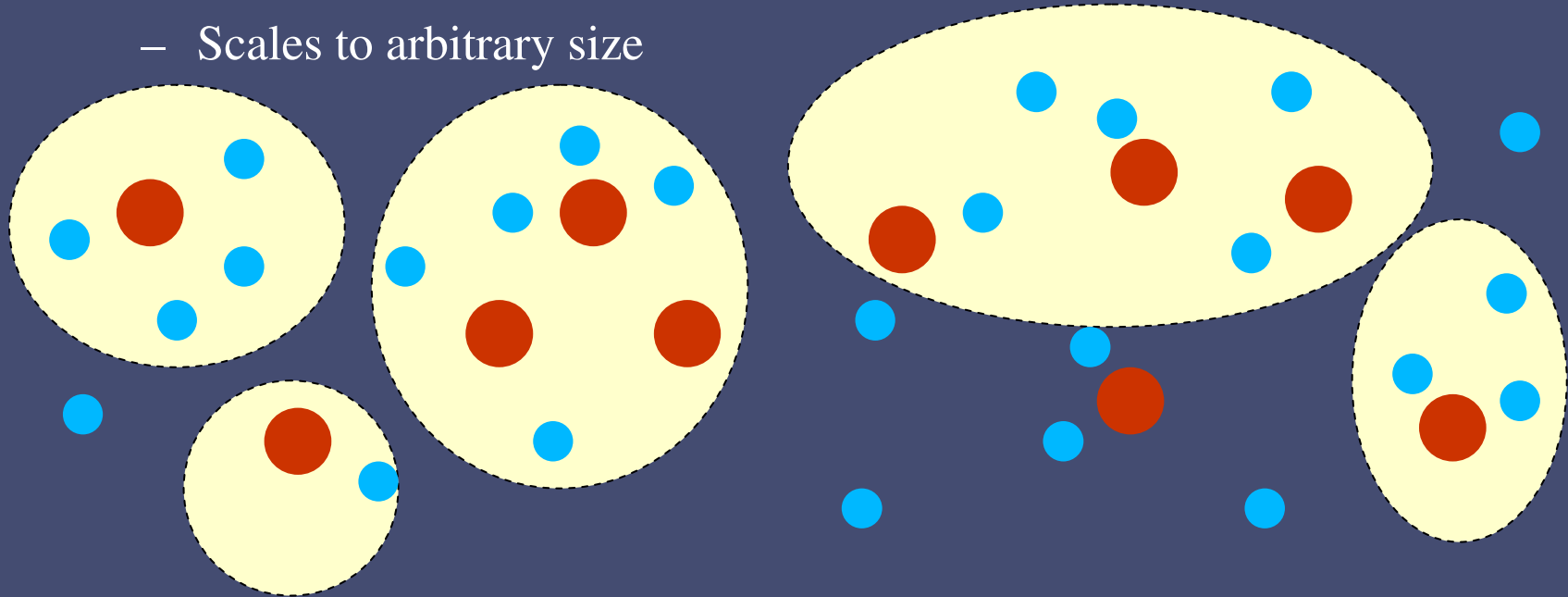
## Toward Autonomic Network Management

- The complexity problem in network management can be abstracted as an instance of the problem of *engineering complex systems*
- Possible approach: *AUTONOMICITY*
- An autonomic system shows 4 key properties:
  - *Self-organizing* (automated configuration of devices and structures in order to accomplish high-level goals)
  - *Self-healing* (ability to detect faults & take the necessary action to go back to normal operating conditions)
  - *Self-optimizing* (ability to modify behavior to optimize system performance & enhance users satisfaction)
  - *Self-protecting* (ability to discover malicious attacks and take strategies to defend itself)

(from IBM's Autonomic Computing Initiative)

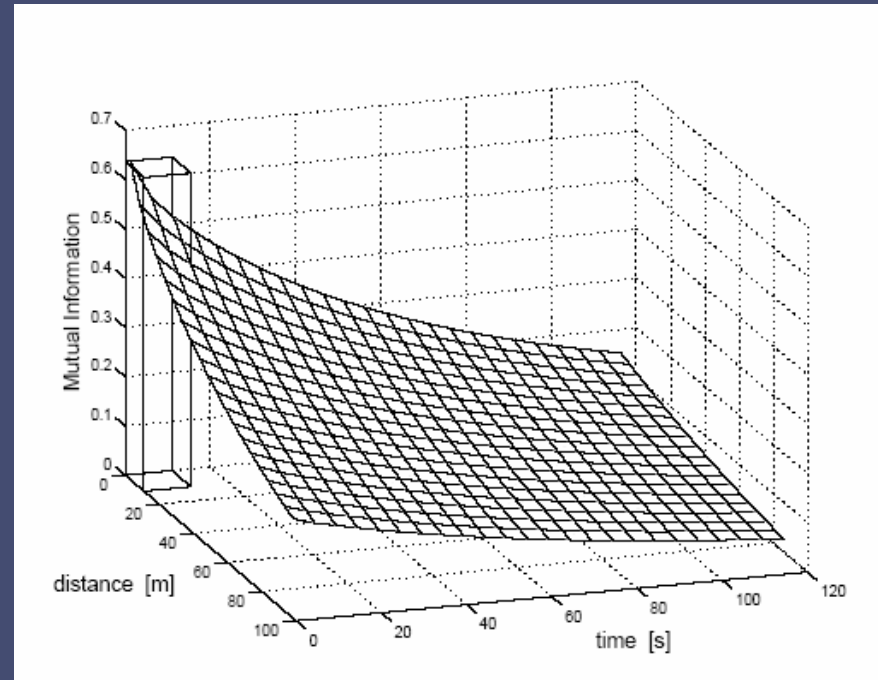
## Solving the Scalability Problem

- ~~E2E~~ P2P architecture: No permanent end-to-end connectivity  
assumption: disconnected operation is normal archipelago of  
(small) dynamic network islands
  - Utilizes unused resources of communication/computation devices
  - Maintains low cost of information oriented devices
  - Scales to arbitrary size



## Data Filtering – P2P motivated

- Usefulness of information decreases in space and time
- Entropy-based filtering
- From Information Theory:  
Derive corresponding decrease in number of bits to transmit information



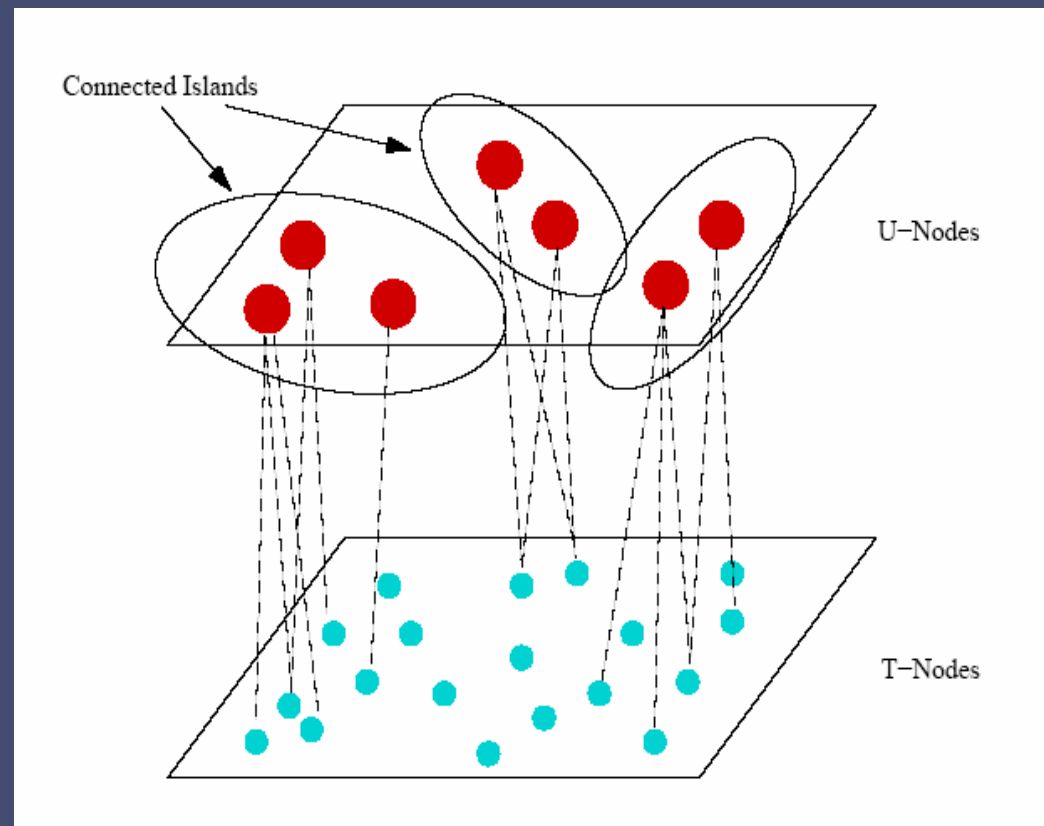
$$\begin{aligned}
 I(x + x_0, y_0, z_0, t + t_0; x_0, y_0, z_0, t_0) &= \\
 &= \pi_0 \pi_1 \rho_X(d, t) \log \frac{\left[1 + \frac{\rho_X(d, t) \pi_0}{\pi_1}\right] \cdot \left[1 + \frac{\rho_X(d, t) \pi_1}{\pi_0}\right]}{(1 - \rho_X(d, t))^2} + \\
 &+ \pi_1^2 \log \left(1 + \frac{\rho_X(d, t) \pi_0}{\pi_1}\right) + \pi_0^2 \log \left(1 + \frac{\rho_X(d, t) \pi_1}{\pi_0}\right) + \\
 &+ 2\pi_0 \pi_1 \log(1 - \rho_X(d, t)).
 \end{aligned}$$

*I. Carreras, I. Chlamtac, F. De Pellegrini, D. Miorandi (Create-Net), "Bio-Inspired Networking for Pervasive Communication Environments", Trans. of Vehicular Tech.*



## Solving the Cost Problem

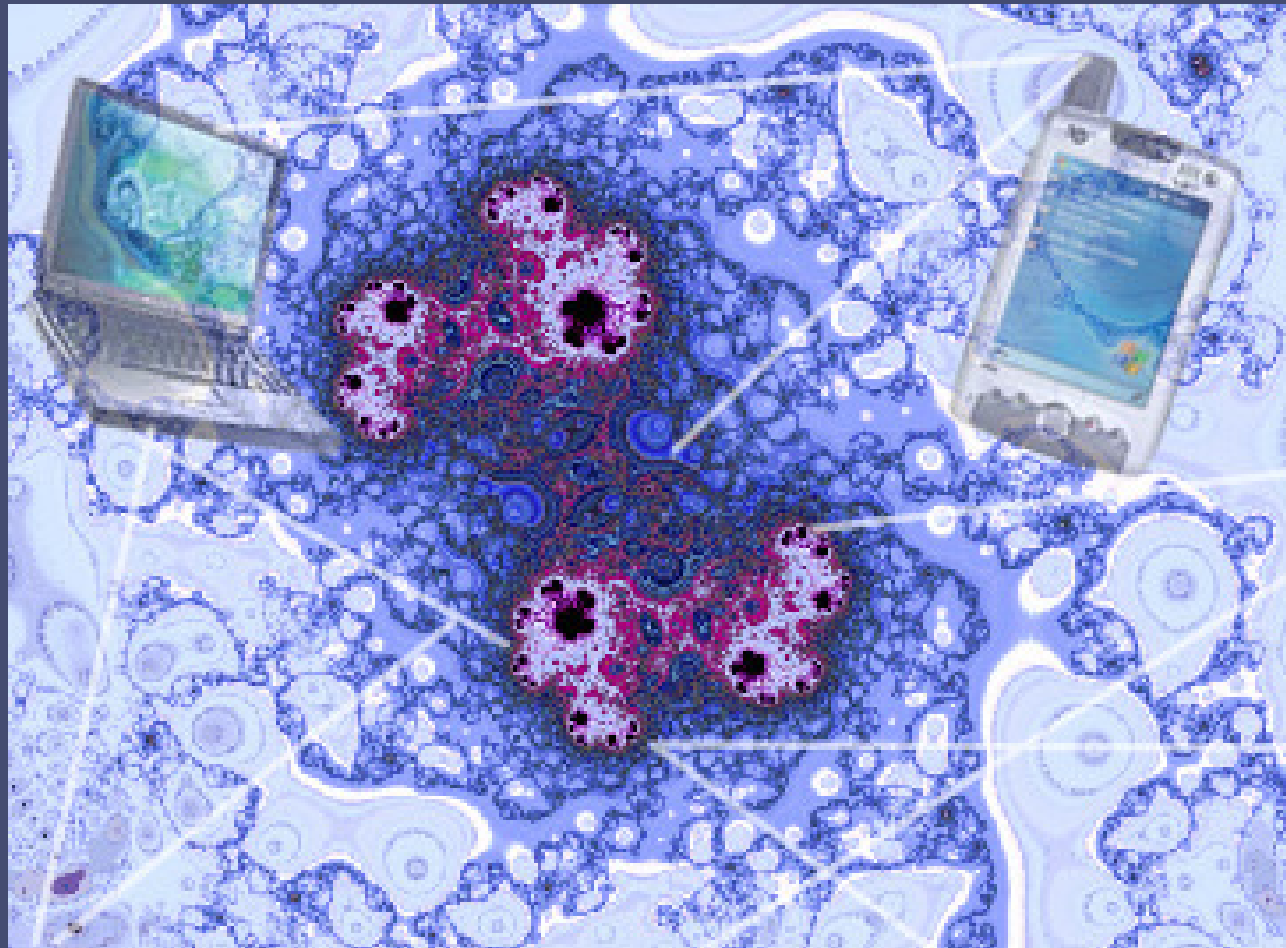
- Two-tier architecture
  - **Mobile user devices**, huge unused capacity collect data while providing rich network and service functionalities over P2P mobile backbone
  - **Low cost data collection devices**, limited resources minimal cost and complexity
- P2P information exchange exploits local information / intelligence and unused capacities



## Services in a Disappearing Network?

- New communications paradigm imposes a fundamental challenge requiring a revolutionary solution:
  - Services: localized, user-situated, decentralized, dynamic...  
**self-managing and adapting**
  - Human-dependent management not feasible
- Solution based on best example around: **living organisms**  
**Bio-inspired**

# Bio-Inspired Computing + Communication



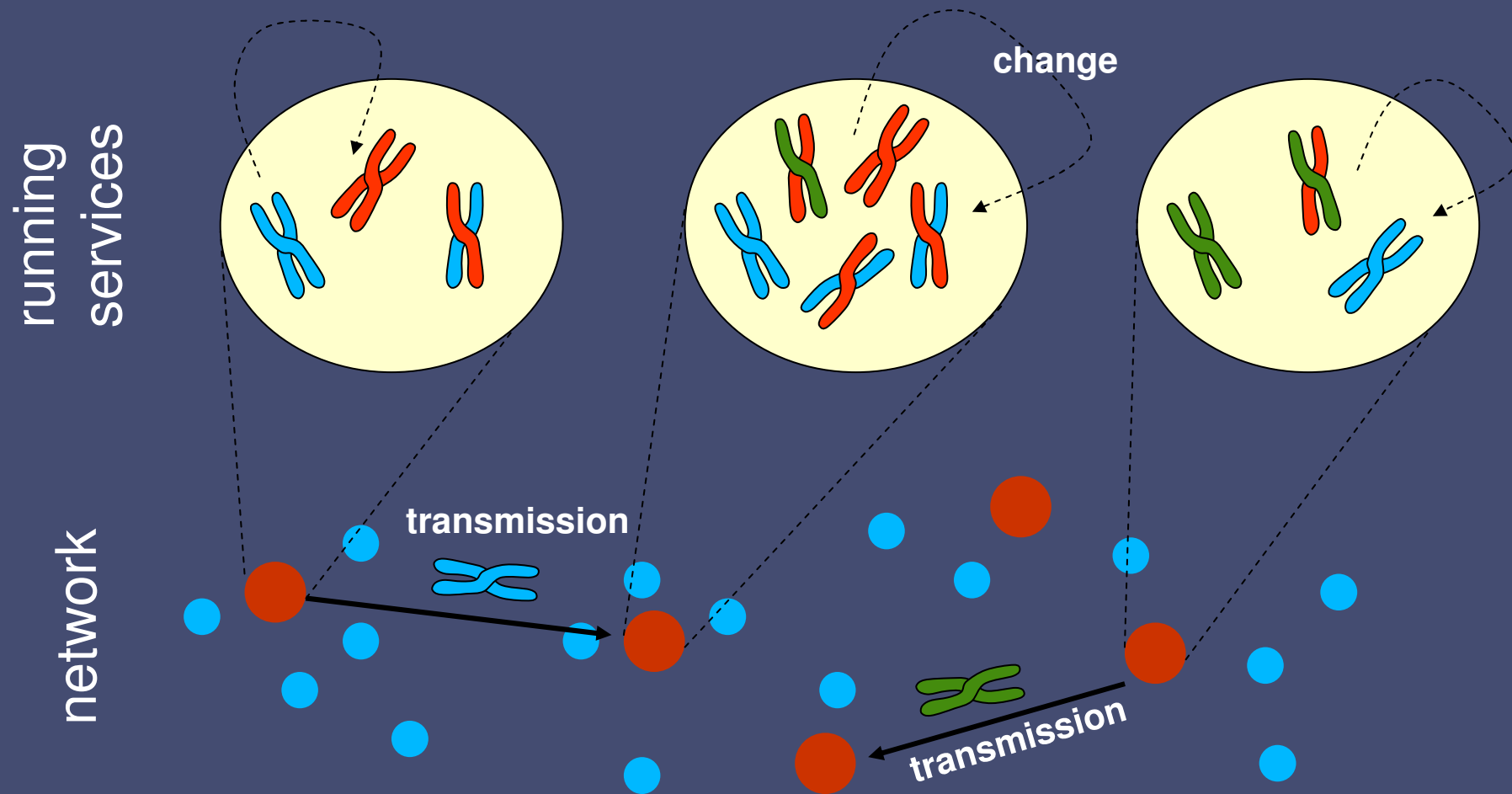
## When Complexity Becomes Life and Intelligence?

- Self-organizing and evolutionary systems amaze us with their ability to construct order against the odds, i.e. to defeat entropy
- A distributed, dynamic, and intelligent architecture of a system allows it to learn from the flow of information it mediates, adapt over time to the needs of its users, and achieve self-organization while remaining essentially a passive system with memory

# Bio-Inspired Service and Network Management

- Service/protocol adaptation by evolution in the way organisms evolved in nature
- Evolvable properties (parameters, code,...) encoded as “genes” in service “chromosomes”
- Natural selection: survival of the fittest service fitness: measure of performance, e.g. user satisfaction
- Genetic operators (mutation, crossover) applied to chromosomes to create new service variants
- Population of services spread through network via mobile P2P communication (and over fixed) network backbone

# Runtime Service/Protocol Evolution



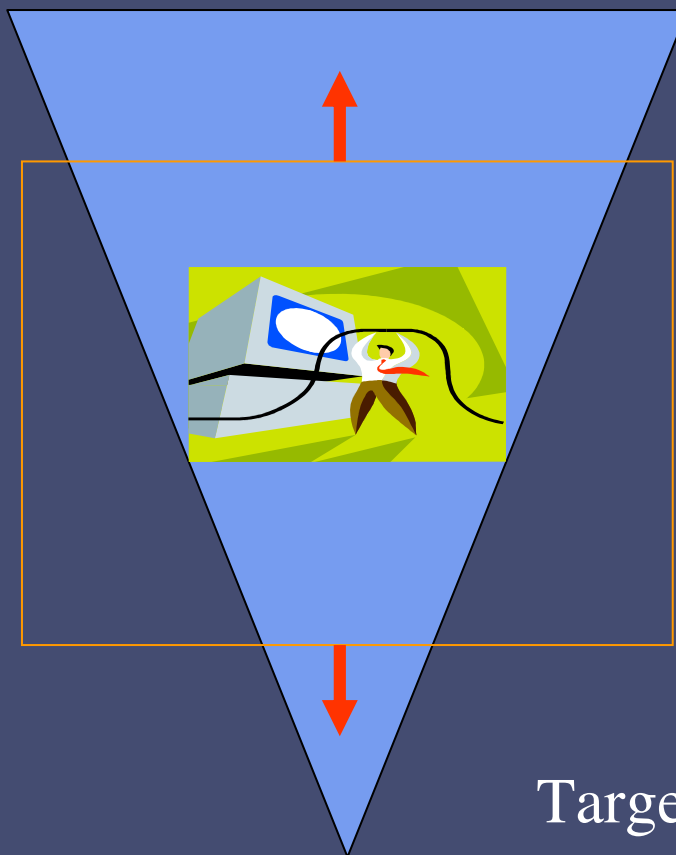
## From Autonomic Services to New Opportunities

- Services which evolve autonomically can be built and accessed individually for building opportunities for SMEs, a critical driving economic engine
- Research challenges
  - **Distributed & asynchronous** evolutionary processes
  - Creation of **viable** and **non-disruptive** service variants
  - Trustable and robust **decentralized fitness evaluation**
  - **Resilience** to potentially harmful mutants

# Technology Trends: Frontiers of Communication



$10^9$  m  
 $10^7$  m  
 $10^{-6}$  m  
 $10^{-9}$  m



User defined services



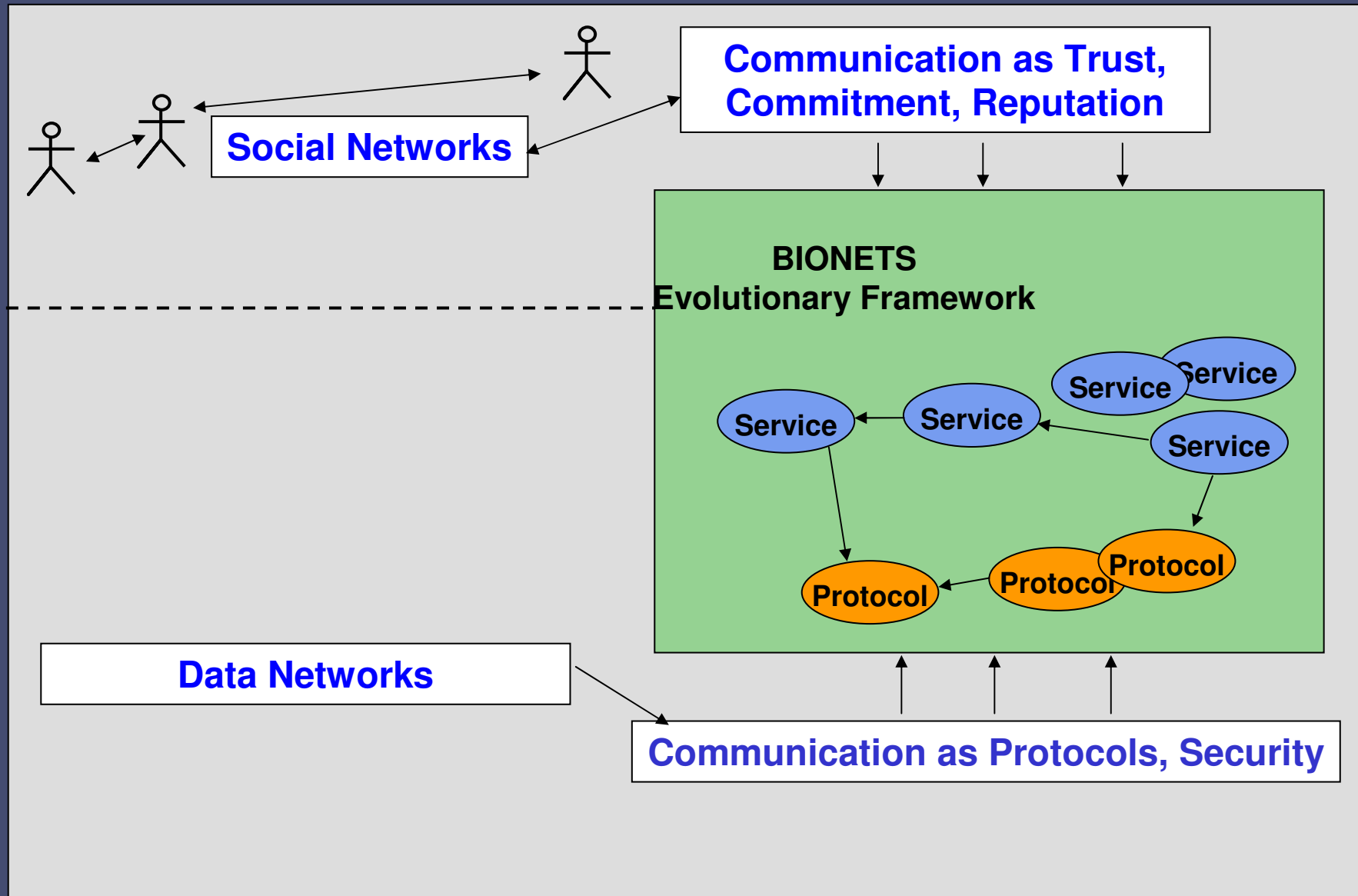
Targeting the extremes of the scale



## Beyond Technology

- Life sciences based communication mechanisms can bring together the socio-economic world of people and the technological world of communication systems
- Biologically-inspired approach coupling genetic and social evolutions
  - Evolution by “natural selection” (survival of the fittest) driven by service needs
  - Security driven by social networks and trust: evolutionary, adaptive security
  - Man machine interaction
- Consequence: change the way people co-exist with information opportunities

# Bridging the Two Views



## European Research Initiatives

- Future and Emerging Technologies program
- “Situating and Autonomic Communications” (SAC) initiative launched in 2004 with a 26ME budget
- The largest 12 partner project, Create-Net, Nokia, Sun,...
- To be enlarged in FP7 (2007-2013) framework program, where Information and Communication Technologies scheduled for a 10 digit budget



## CREATE-NET's Mission

- CREATE-NET (Center for REsearch And Telecommunication Experimentation for NETworked communities) founded as consortium of research institutions
- In cooperation with the European Commission and industry turns ideas into products and global competitiveness
- Performs research, technology transfer and information dissemination in
  - Novel frontiers of core Internet technologies
  - Digital business ecosystems
  - Ambient and pervasive environments
  - Emerging security solutions...
- Internationalization and globalization of research to build value through cooperation



*Building the global networked  
society of the future*



*[www.create-net.org](http://www.create-net.org)*