BT's networking research goes holistic

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summary

- pure technology research no longer sufficient in networking

- hard research issues cross discipline boundaries into economics and the social sciences, including mgmt science & public policy

- selection of BT research projects to illustrate trend of priorities

- insufficient to be jacks of all trades and masters of none

- major research advances through excellence in multiple fields

- trend still balanced by more traditional technology research

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- major ICT provider
  - UK telecoms & global datacomms
  - global ICT integrator
  - research now a tiny but influential part (500/110,000 employees)
    - all based at Adastral Park, near Ipswich
- 21CN: hugely ambitious technology rationalisation
  - 21st Century Network
  - converging all infrastructure to IP & componentising systems
  - 2003: first telco (and still one of the few in the world) to commit
    - Nov '06 start switching from PSTN
    - Dec '08: 50% PSTN switched off
   - Apr '05: £10B tender completed, now interop testing

the rise of cross-discipline research
a short history of the networks research centre

- early '90s distributed systems research group
  - ODP, CORBA etc, mostly intra-enterprise scenarios, some inter-

- 1994: Web e-commerce
  - we built trial selling BT products before Netscape formed

- the big problems became
  - how to scale the number of players in a distr.system without trust?
    - groups: multicast or overlays: group auth'n, key mgmt etc
    - replace identity with anonymous purchase of rights – a market
  - we're all arguing based on intuition
    - what is the science of distributed systems?
    - combining economics, physics, information theory, channel theory, etc
    - can we articulate our intuitions?

- internetworked information now factors into geopolitics

networks research – enduring tensions
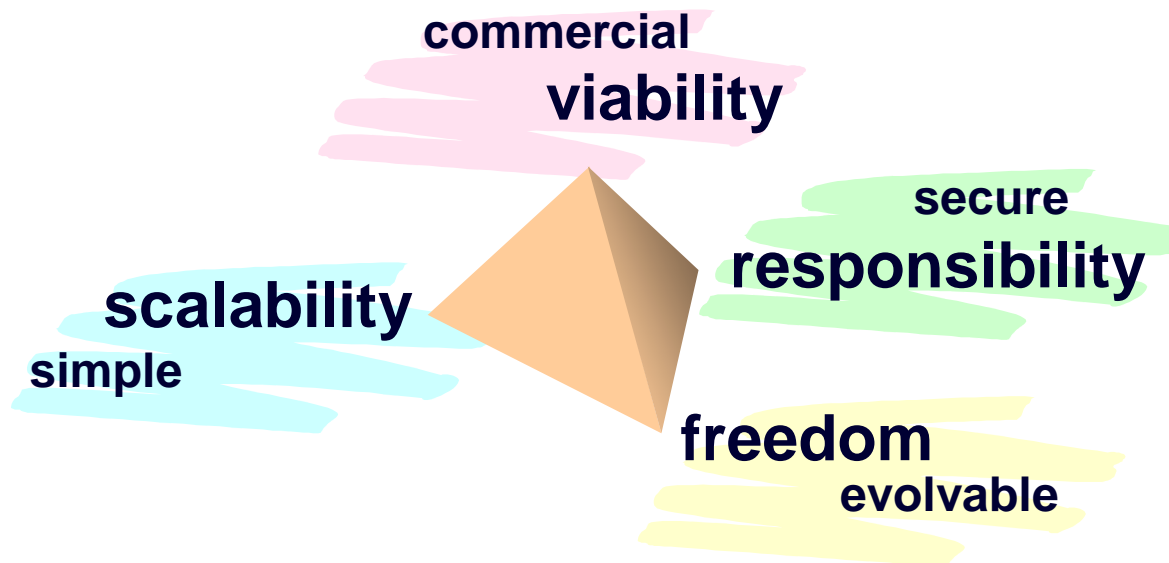
a selection of projects

- network congestion control & QoS

- computational networking

- contractual mobility

- motivational issues in peer to peer networking

- privacy in pervasive computing

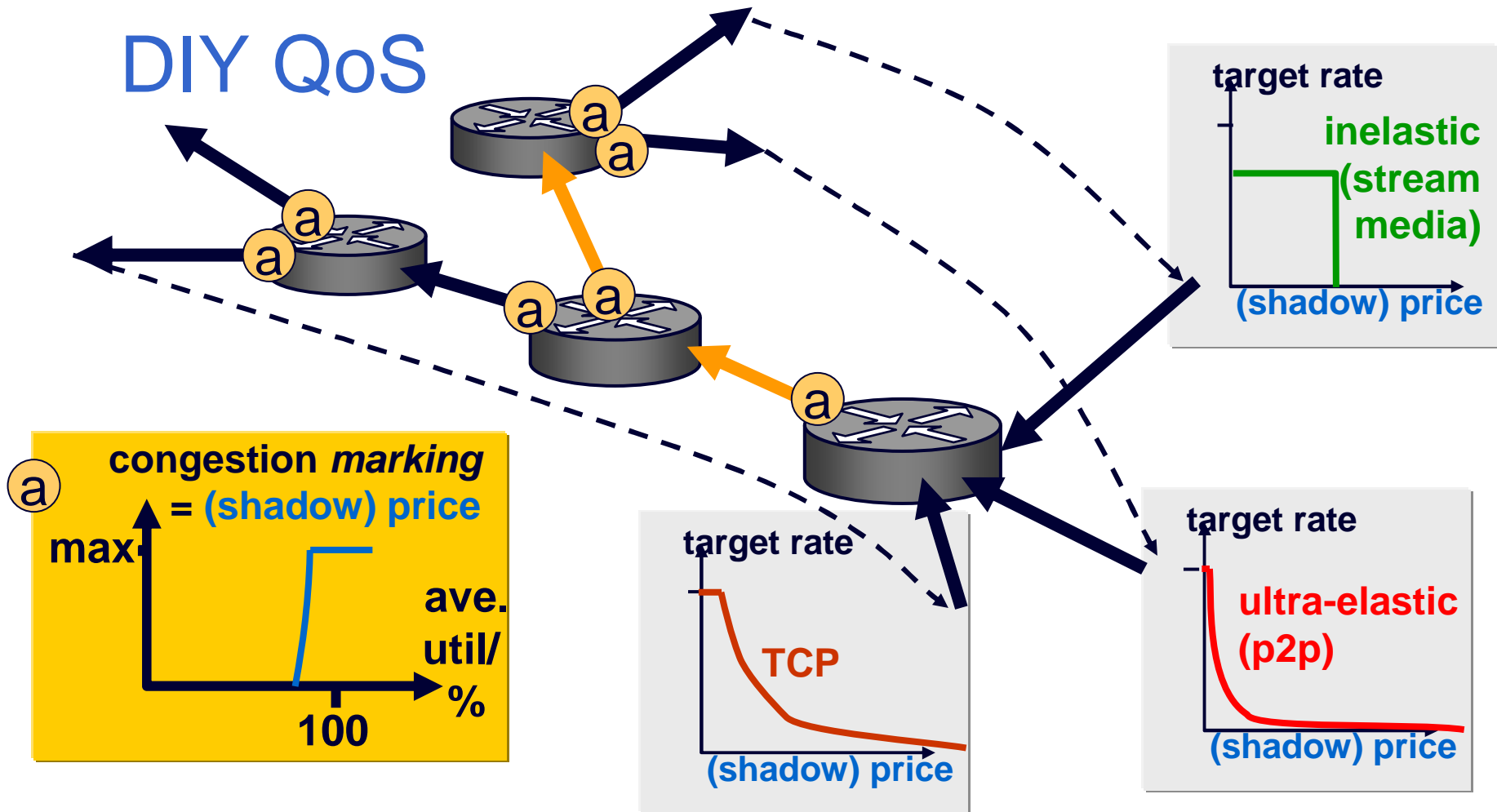- communications research network (CRN)

network congestion control
& quality of service (QoS)

- in retrospect we only needed these steps:

  1. start from the microeconomics

     – Pricing Congestible Network Resources,
       MacKie-Mason & Varian 1995

  2. analyse game as linear programme in a datagram network

     – Rate control for communication networks: shadow prices,
       proportional fairness and stability, Kelly, Maulloo & Tan 1998

  3. develop various business models to manage risk

 4. make it all practical in current networks

DIY QoS

target rate

inelastic (stream media)

(shadow) price

congestion *marking* = (shadow) price

max

ave. util/ %

100

target rate

TCP

(shadow) price

target rate

ultra-elastic (p2p)

(shadow) price
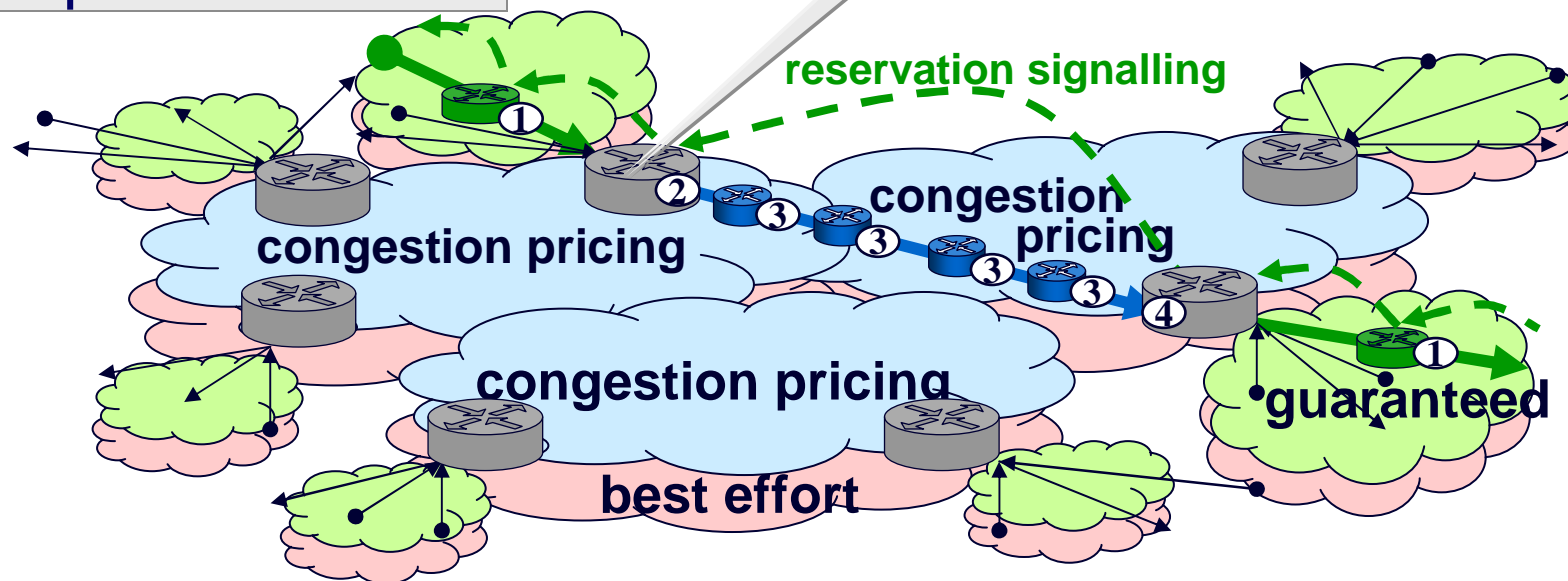
- using congestion marking of IP header (explicit congestion notification - ECN)
- Kelly showed applying a price to the marks led to optimal resource alloc
- users created their own QoS by responding differently to congestion
  - *nearly* practical, but receivers had to carry the risk of price variation

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synthesise QoS guarantees
using pre-congestion notification
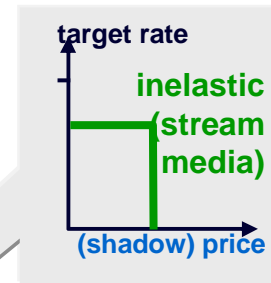
IP routers		Data path processing	
Reservation enabled		①	**Reserved flow processing**
RSVP/ECN gateway		②	**Policing flow entry to CP**
		④	**Meter congestion per peer**
ECN only		③	**Bulk ECN marking CP prioritised over BE**

➔ **most practitioners oblivious to economic foundations**
➔ **better guarantees than complex reservation systems**
➔ **core: classic Internet with minor mods**
➔ **neither overprovisioning nor QoS smarts**
➔ **BT, Cisco, Nortel & Ericsson standardising in IETF**

target rate

inelastic (stream media)

(shadow) price

reservation signalling

congestion pricing

congestion pricing

congestion pricing
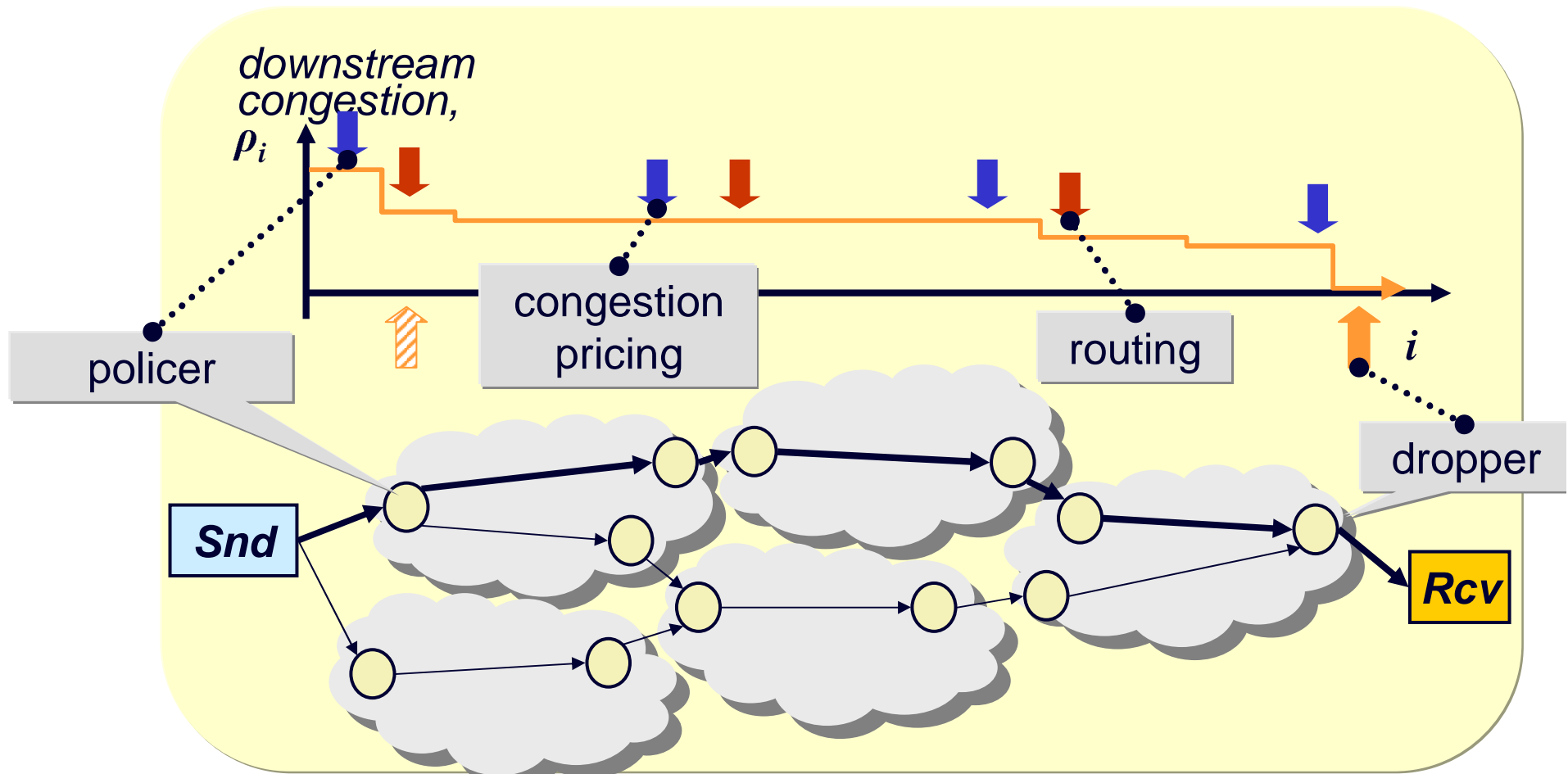
guaranteed

best effort

- an instance of the inelastic response of DIY QoS
  - but edge gateways (grey) carry risk rather than receiver

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re-feedback incentive framework
general congestion ctrl & QoS for datagram internetworks

- same as DIY QoS, but risk moved to sender
- then ingress network can broker risk purely at network layer

IP End to End Quality of Service
– we also do traditional technology research

21CN QoS design & validation

Access, backhaul, core & interconnect:
all very different problems
• access no trusted IP node upstream
• backhaul, simple star, but QoS must
survive lower layer failure restoration
• core & interconnect: scalability

End   Home   Access   Core   Core   Core   Access   Home   End
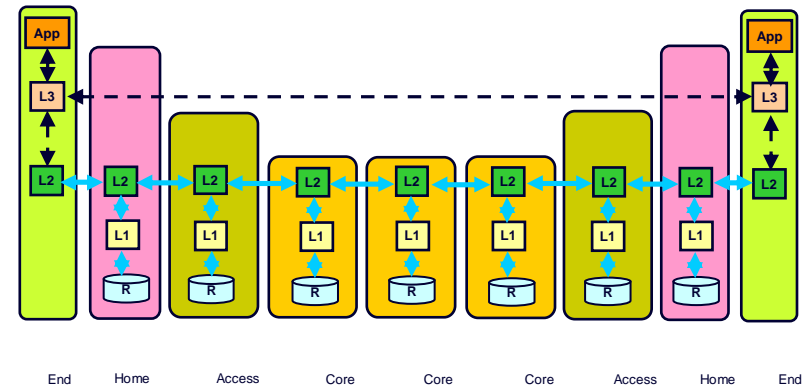
End to End QoS Coordination
Signalling across heterogeneous
technologies and fiefdoms

WLAN – 802.11e

2 QoS Modes:
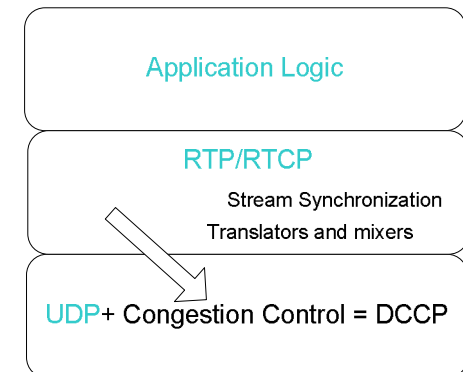• Priority (EDCA) – simple but non
efficient for small packets
• Polling (HCCA) – complex and
still affected by interferance
Little info on how to set parameters
or integration into e2e QoS system
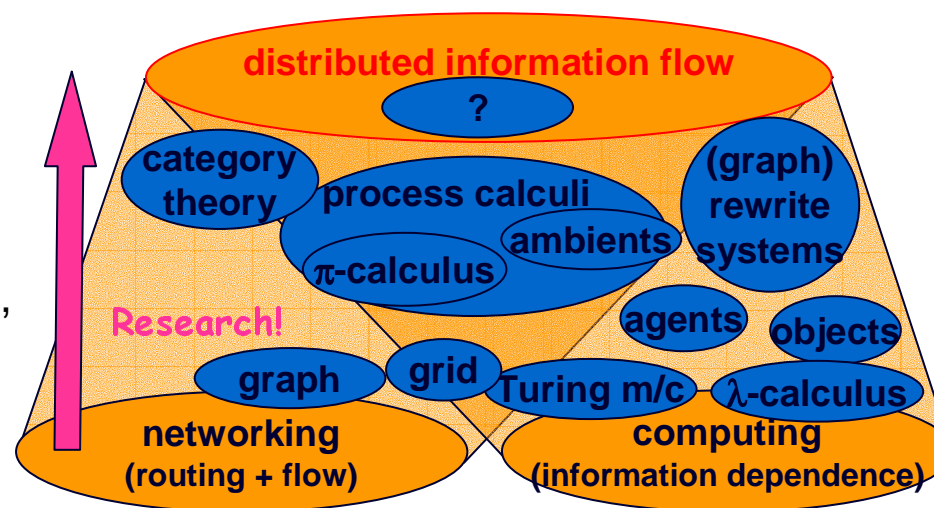
Congestion Collapse & DCCP

Congestion collapse as
non rate adaptive UDP
traffic increases

Application Logic

RTP/RTCP
Stream Synchronization
Translators and mixers

UDP+ Congestion Control = DCCP

computational networking
process model

- Can implement typical network processes
  - routing ⊕ congestion pricing = congestion routing

- Provides an alternative view on (distributed) computing
  - convergence vs. transition
  - interaction vs. input/output

- Connects with
  - Economics, game theory
  - Constraint and functional programming, message passing
  - Dynamic systems, control theory, optimisation
  - Electronic circuits, thermodynamics

- Offers a framework within which to address various research questions within networking
  - layer interaction, feedback, time scales, network economics

distributed information flow

?

category theory

process calculi

π-calculus

ambients

(graph) rewrite systems

agents

objects

Research!

graph

grid

Turing m/c

λ-calculus

networking (routing + flow)

computing (information dependence)

contractual mobility

Dynamic business relationship establishment

- Per-session
- Without the need for any prior agreement
- Involves trust, charging, billing and payment

Automated offer dissemination

- Discovery
- Notification

Automated offer selection

- Policy-based
- Multi-attribute
- Intelligent (with a learning model)

Wide-area coverage

Local-area coverage

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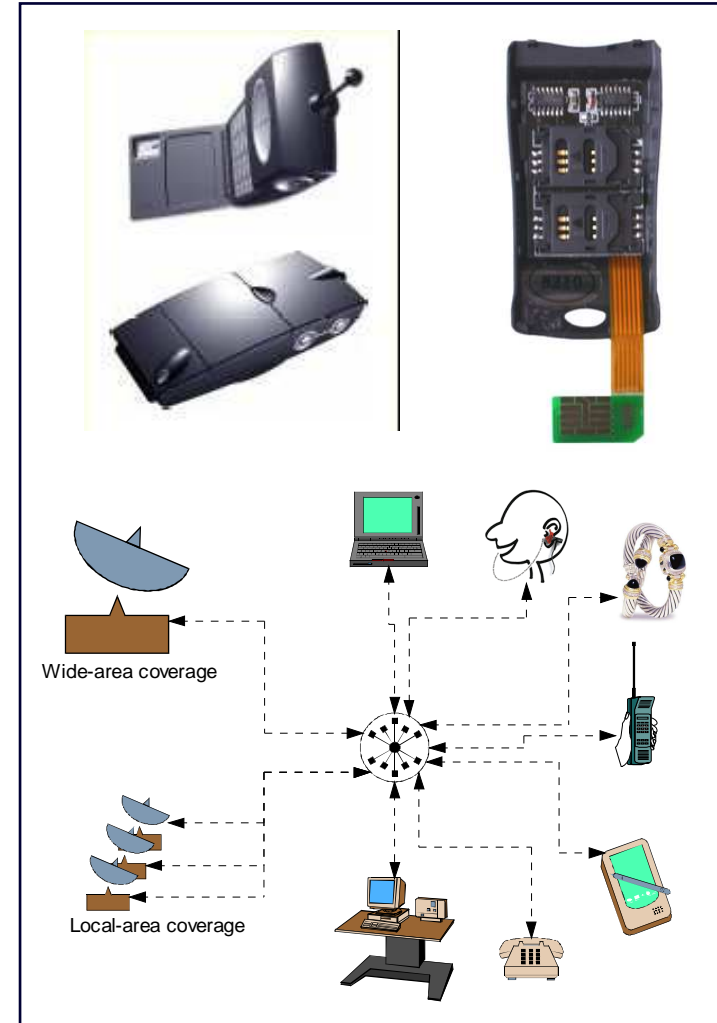
contractual mobility – prototype
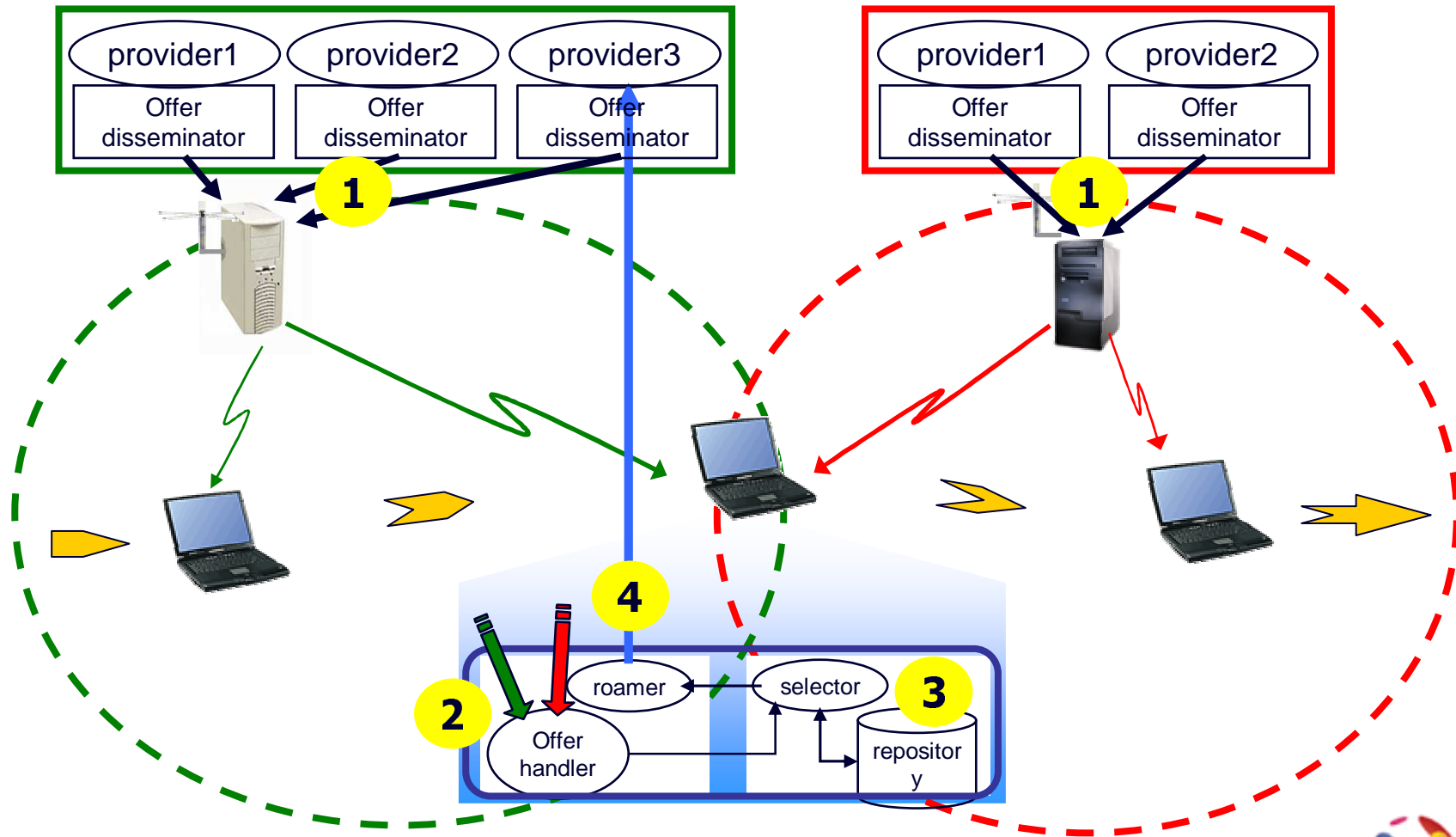
contractual mobility
– policy issues

- **automated selection**

  - by price-quality, by brand

  - provider strategies to keep customers sticky, contract vs. PAYG

- **user-selected edge-provider vs. user-selected route**

  - edge provider competition creates backbone competition?

  - or does the Internet need 'carrier pre-selection'

Motivational Issues in Peer-to-Peer

Edge computers
(Peers)

Minimal use of
central servers

Communicating
directly
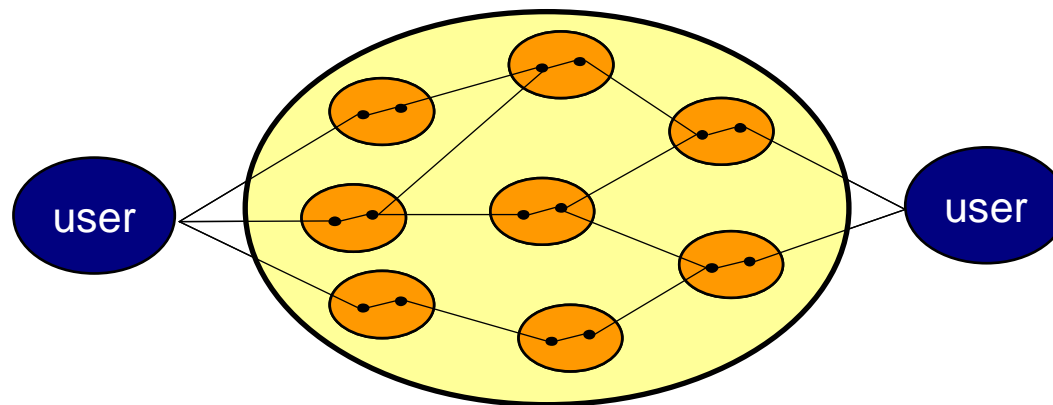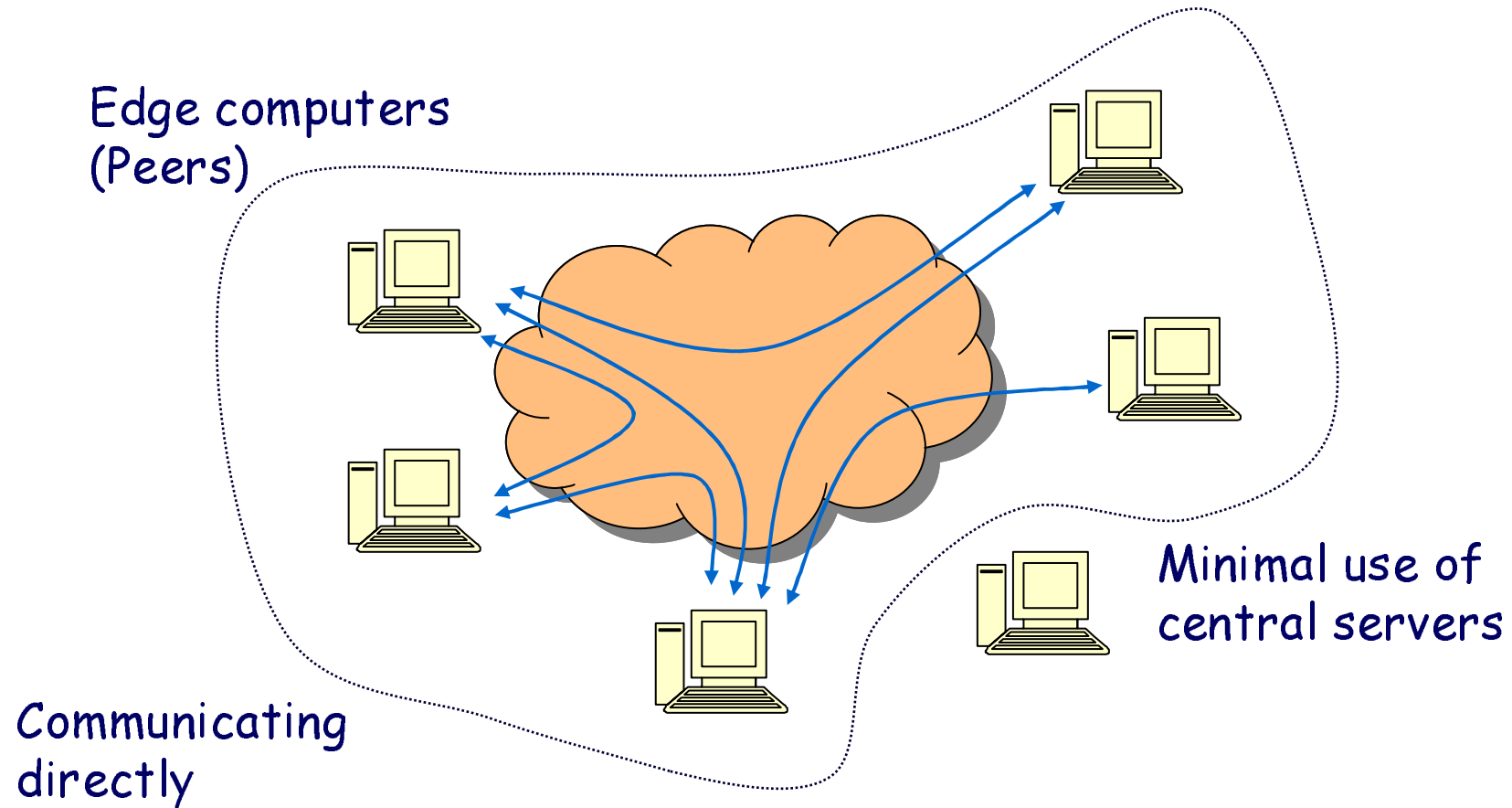
Sharing information or system
resources or (more interesting!)
peoples' time and effort.

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economic architecture
prototype implementation all p2p

In a community context

Consumer   Provider   Other Peers

Social Control

Make the social control explicit

Aggregated Information

Accounting and Distribution

Tokens

Peer Control   *Peer Control*

Service Usage

token

service

Underlying atoms of consumption and contribution
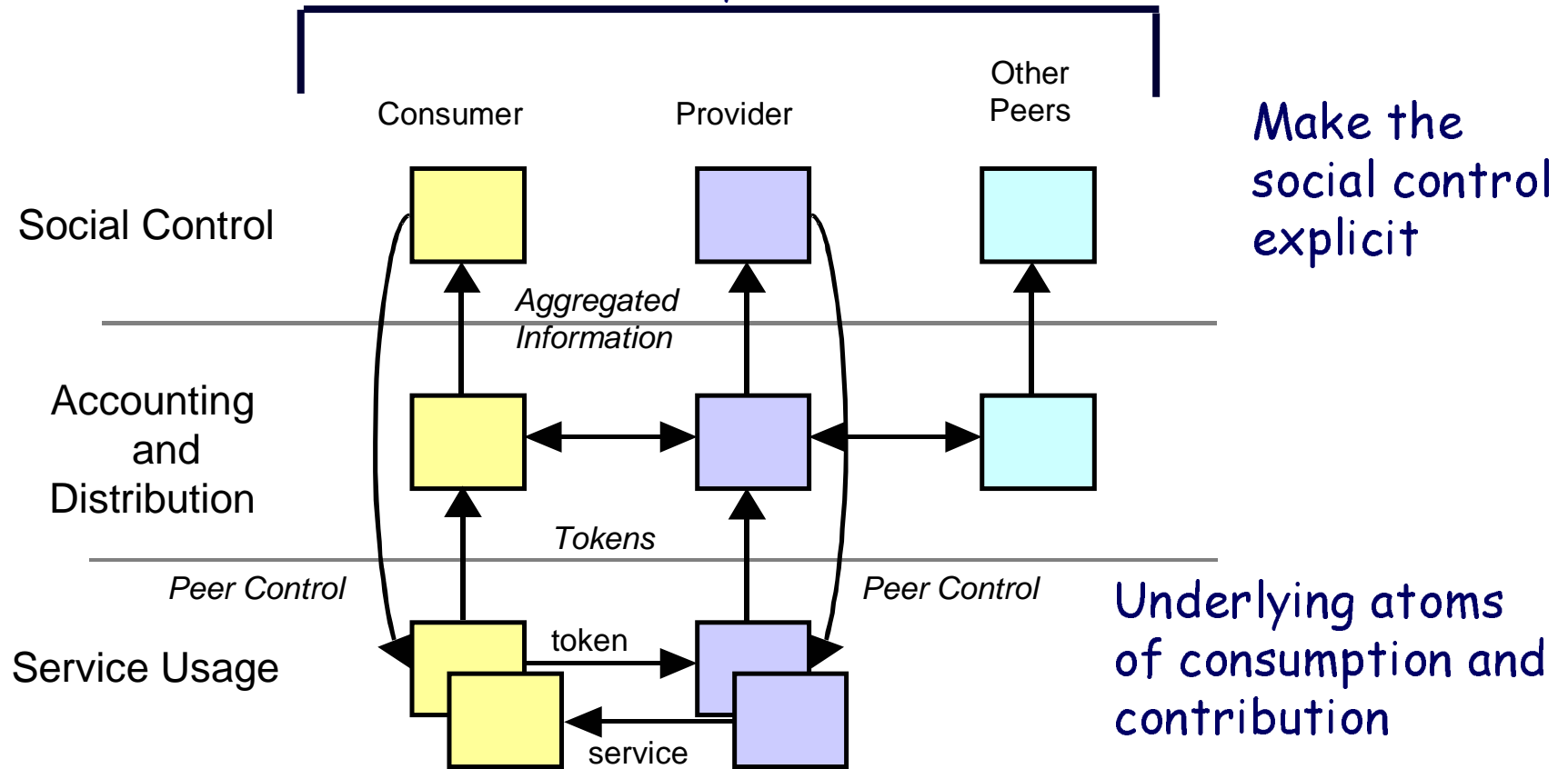
privacy in pervasive computing

Improving service acceptance and value
Releasing value from untapped markets
Developing Privacy Enhancing Technology

Contributing to 21C Network Vision
Privacy Control and Awareness

Targeted solutions
Innovative component technology

Overly restrictive legislation

New valuable services

Too intrusive

No Privacy Enhancing Technology

Users opt-out

value
Participation
Information

Complete Privacy Control

Too costly

Damage to brand

Unusable

Lost market & failed services

Poor uncompetitive services

e.g. post-retail RFID

Mobile

Location

Mary

Engine mgt.

Mobile Location Provider

Satnav

EPCs

Car

Preferences

Location

Seats

Bluetooth ID

Door

Pressure

RFID Tags

Open/Close

Mobile

Dave

Location

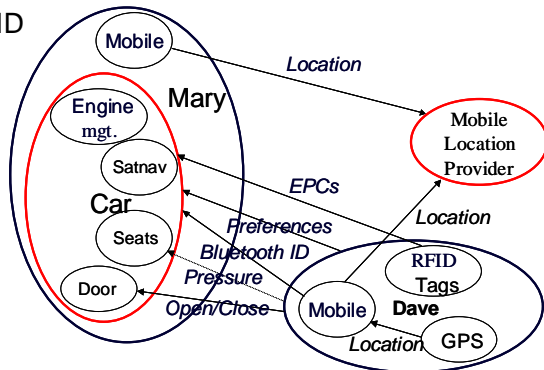GPS

Transport
Information, ticketing, congestion, insurance

Home and office environments
Ubiquitous services, home control, whereabouts

Healthcare & Telecare
Patient records, home monitoring

21C
Presence, Location, Directories, Address Books, Diaries

Supply Chains, Logistics & Retail
RFID Privacy & Security

Collaborations
• UC Berkeley
• Cambridge (TIME EPSRC/WINES)

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what's CRN for?

Communications Research Network

to co-ordinate future health of the

materials & process equip	comp-onents	equip makers	network owners	service providers	content & applics	appli-ances	end users

- why?

- comms industry value chains broken
  - value not flowing to infrastructure
  - unauthorised innovation blocked
  - incumbents holding back change
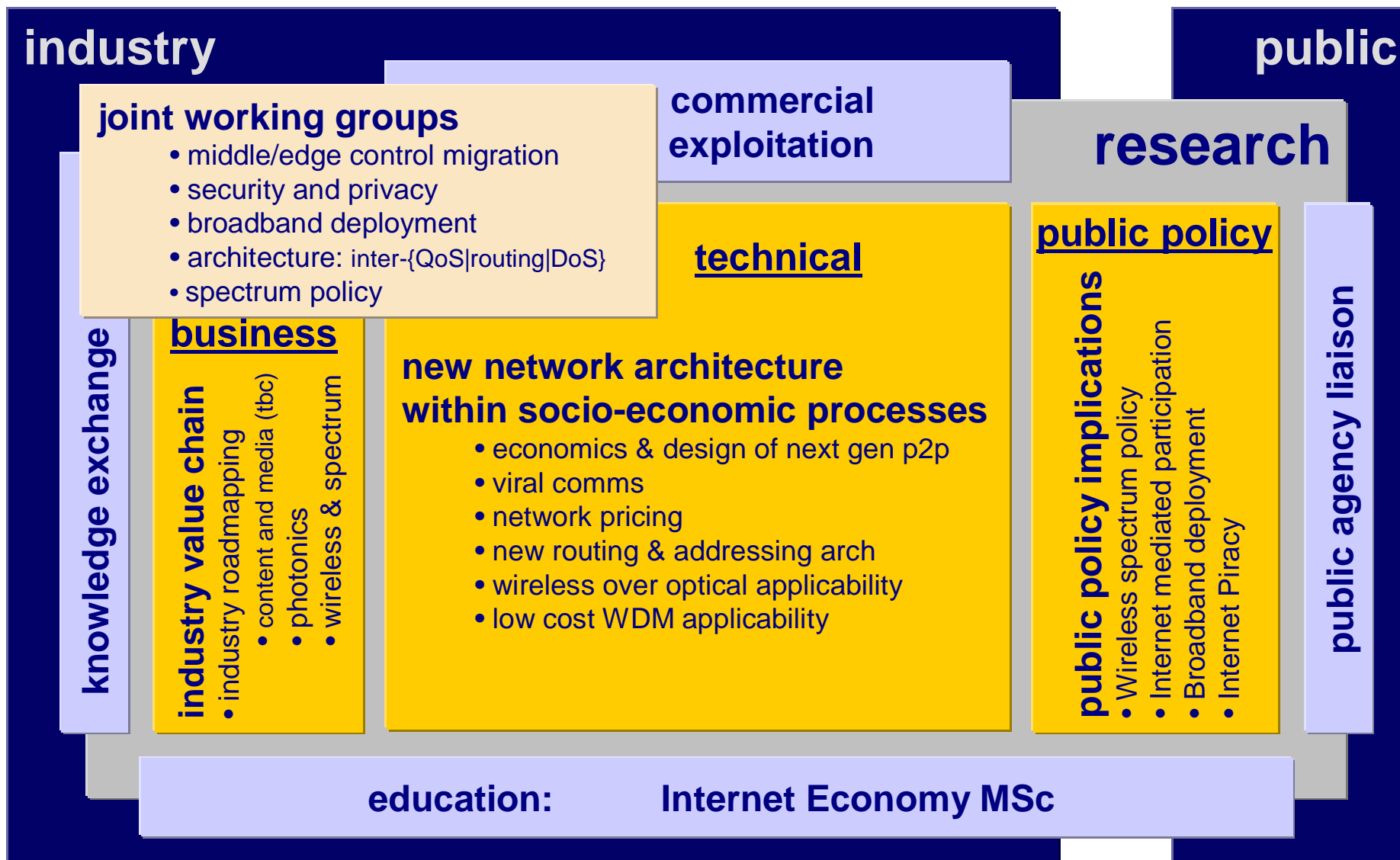 - fear, uncertainty and doubt make investors risk-averse

top industry movers working together
- analysts
- architects
- regulators
- economists
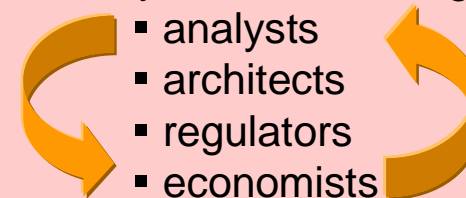
- how?

- industry roadmapping

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working groups – an academia/industry bridge

industry

public

research

knowledge exchange

joint working groups
- middle/edge control migration
- security and privacy
- broadband deployment
- architecture: inter-{QoS|routing|DoS}
- spectrum policy

commercial exploitation

business

industry value chain
- industry roadmapping
  - content and media (tbc)
  - photonics
  - wireless & spectrum

technical

public policy

new network architecture within socio-economic processes
- economics & design of next gen p2p
- viral comms
- network pricing
- new routing & addressing arch
- wireless over optical applicability
- low cost WDM applicability

public policy implications
- Wireless spectrum policy
- Internet mediated participation
- Broadband deployment
- Internet Piracy

public agency liaison

education: **Internet Economy MSc**

an unrepresentative snapshot of BT's research

|	main research centres	networks	pervasive computing	mobility	broadband	intelligent systems	IT	security	foresight
core research	today's slides	■	■	░				░	
roadmapping, alerts, trends		░		░			░		■
product /service concept demos		░	■		■		■		
product evaluation /integration				■	░		░	■	
advance development						■			

... but the leading edge of a trend

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networks research centre – soft themes

- networks of x
  - x: computers, devices, people, physical phenomena
- necessity of relaying infrastructure?
  - commercial service vs. collaborative self-supply
  - questioning the end to end design principle
- incentives
  - for collaborative self-supply
  - to offer a commercial service (viability)
  - social costs (e.g. congestion, loss-of-privacy)
- regulation & public policy
- general principles for design and analysis
  - intuitive new design principle built on case studies in designing for tussle
    - architect the system so it allows the best suited solutions to emerge and evolve
  - scientific framework for reasoning, proof, architecture, language, implementation

commercial
viability

secure
responsibility

scalability
simple

freedom
evolvable

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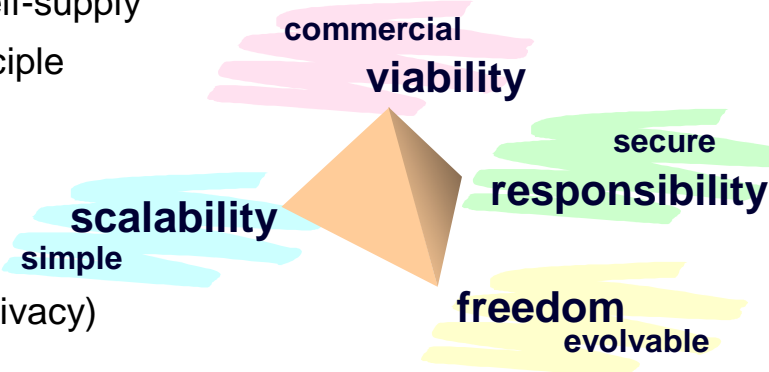
networks research centre - expertise

- networking architecture, layering, interconnect, naming & addressing

- network games, network security

- network pricing, business models

- optimisation, process algebra

- network protocol engineering & technology

- distributed systems, platforms

- messaging, group communications

- technical, economic, social

more info

- network congestion control & QoS
  - <www.cs.ucl.ac.uk/staff/b.briscoe/pubs.html#ipcharging>
- computational networking
  - <nigel.g.walker@bt.com>
- contractual mobility
  - <cfp.mit.edu/groups/broadband/broadband.html> (Personal Broadband)
- motivational issues in peer to peer networking
  - <www.mmapps.org>
- privacy in pervasive computing
  - <Andrea.2.Soppera@bt.com>
- communications research network (CRN)
  - <www.communicationsresearch.net>
- Bob Briscoe
  - <www.cs.ucl.ac.uk/staff/b.briscoe/>