

# Quel futur pour les options de routage ?

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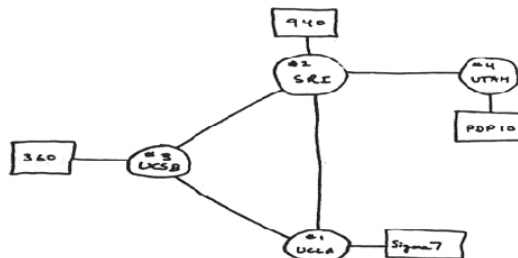


Once upon a time ...



## The beginning ...

"In the Beginning, ARPA created the ARPANET. And the ARPANET was without form and void. And darkness was upon the deep. And the spirit of ARPA moved upon the face of the network and ARPA said, 'Let there be a protocol,' and there was a protocol. And ARPA saw that it was good. And ARPA said, 'Let there be more protocols,' and it was so. And ARPA saw that it was good. And ARPA said, 'Let there be more networks,' and it was so."-- Danny Cohen



THE ARPA NETWORK

DEC 1969

4 NODES

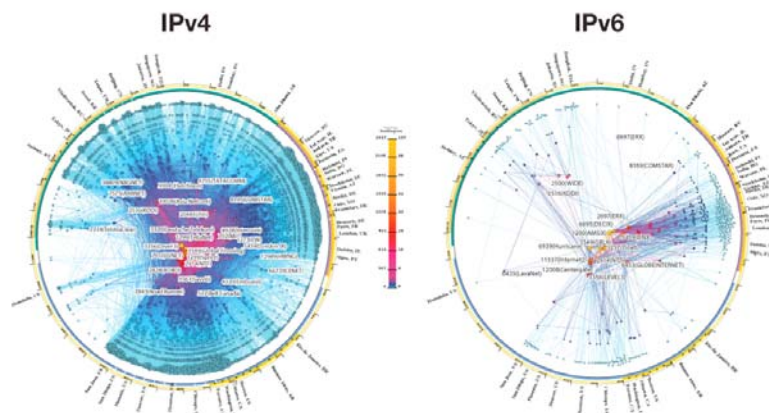
FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)

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## And now ...

IPv4 & IPv6  
INTERNET TOPOLOGY MAP  
JANUARY 2009

AS-level INTERNET GRAPH



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## What we have got !!

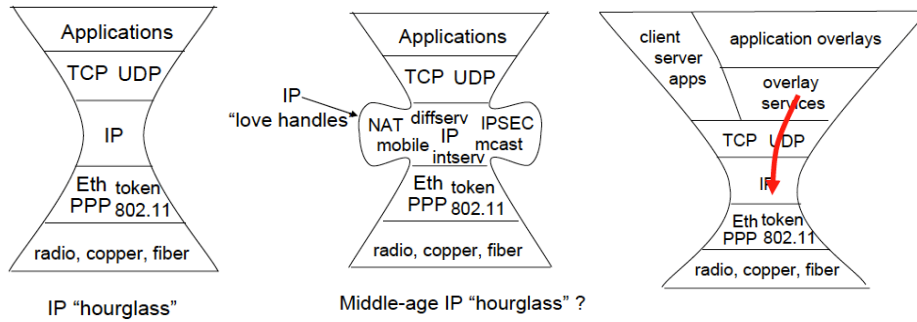


## Happy birthday !

- Three anniversaries in 2009
  - 20 years of Web
  - 30 years of USENET
  - 40 years of ARPANET
    - approaching middle age



## middle age: a narrowing mind, a widening waist or



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## And ... the future



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## The future ?

- It is hard to see the future .....
- but maybe we can say what future should not be !
  - and even we would like it to be !

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## Requirements ?

- Various stakeholders have differing/conflicting requirements
  - End Users vs. Telecommunications Service Provider vs. Regulators
  - Protocol Developers vs. Standardization Bodies vs. Hardware & Software Manufacturers
  - Application Developers vs. network designers
  - Military & Security authorities vs. civil rights
- **Conclusion: No "one-size-fits-all" solution**
  - What to do? Would heterogeneity reign?
  - Current Internet cannot afford yet another patch !
- Architecture will need to adapt to future (unknown) needs

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## What is wrong with IP?



- 1. What is IP and what are IP addresses?
- 2. How does routing in the Internet works?

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## Addressing

- Addressing goals:
  - Identification = who
  - Location = where
  - Content = what
  - «An IP address does not identify a specific computer. Instead, each IP Address identifies a connection between a computer and a network.» [Computer Networks, D. Comer]
- Routing is a function that accepts Id, Loc, Con and generates a path to the goal
  - Routing = find a way to destination
  - Forwarding = send next hop on the way

So, if you don't get this mail because I wrote the wrong address again, please reply to me a.s.a.p.

Best,  
Bob



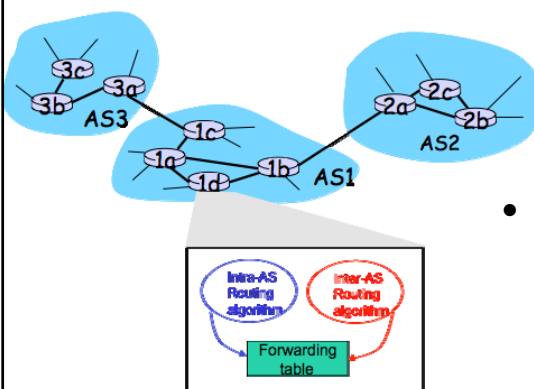
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## Ip Address ?

- «An IP address does not identify a specific computer. Instead, each IP Address identifies a connection between a computer and a network.»  
[Computer Networks, D. Comer]
- What's happens if the location/person/content changes
  - Mobility, Hadopi, dynamic changes
- Solutions adopted so far :
  - Patches, and patches over patches, in contradiction with the initial design paradigms
    - Mobile IP, authentication, Google, etc.
  - Incoherencies
- Consensus in the research community that a next step beyond the Internet

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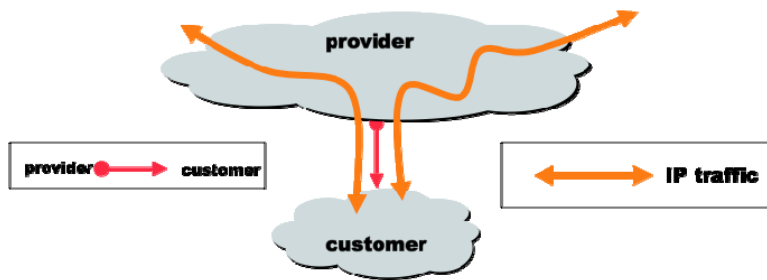
## Two levels architecture



- Intra AS (IGP)
  - OSPF, ISIS, RIP
    - distance based
    - Intra-AS sets entries for internal dests
  - Routing based on IP address
- Inter AS
  - BGP
    - Policy based
    - Inter-AS & Intra-As sets entries for external dests
    - Routing based on AS number and/or IP address mask

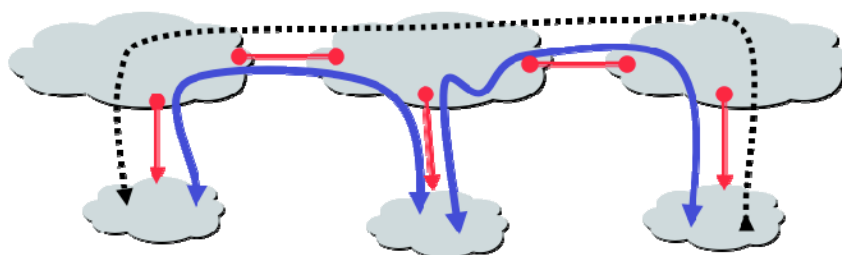
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## How Inter-net works ?



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## How internet works ?



Peers provide transit between their respective customers

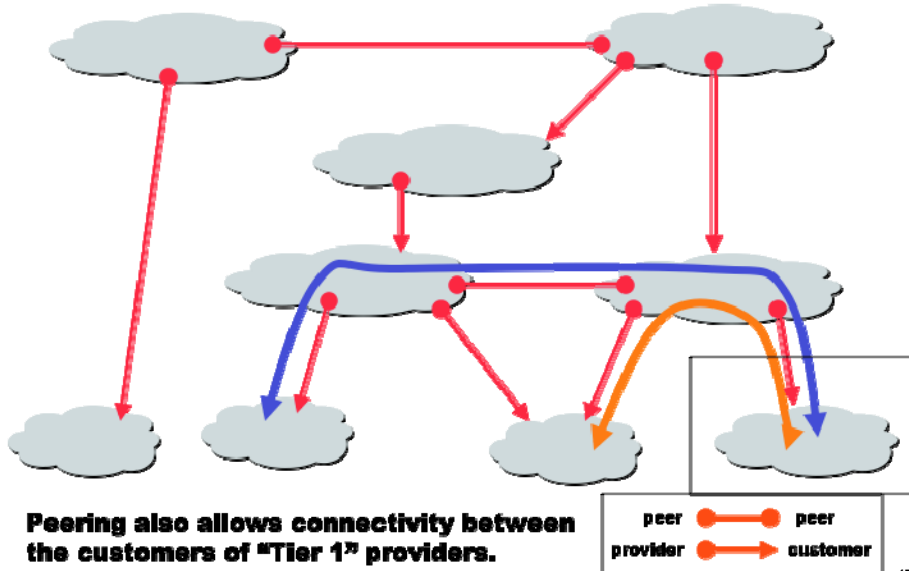
Peers do not provide transit between peers

Peers (often) do not exchange \$\$\$

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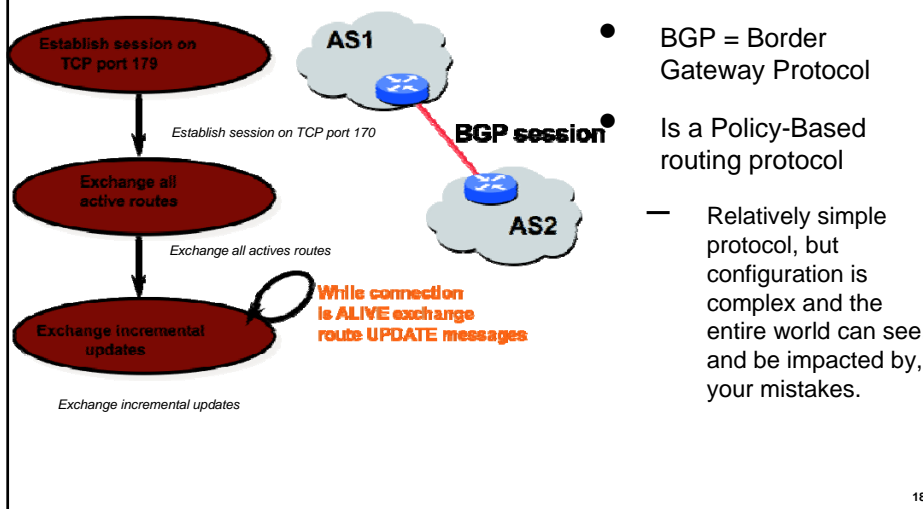


## Peering ?



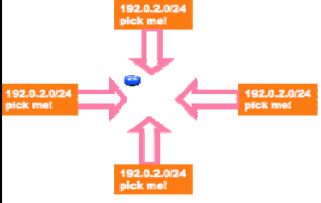
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## BGP ?




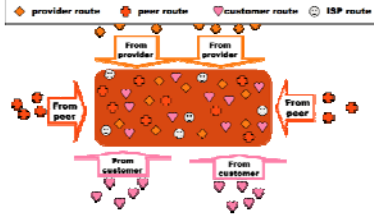
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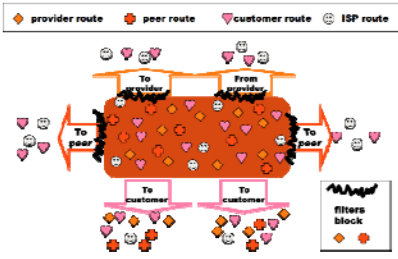
## «Le Grand Jeu»



- BGP filtering and Injecting
  - Hot potatoes routing
  - Enforcing policies
  - Competition playground
- Need for governance
  - To avoid the pakistaneese «mobilette»
  - To fill the internet divide

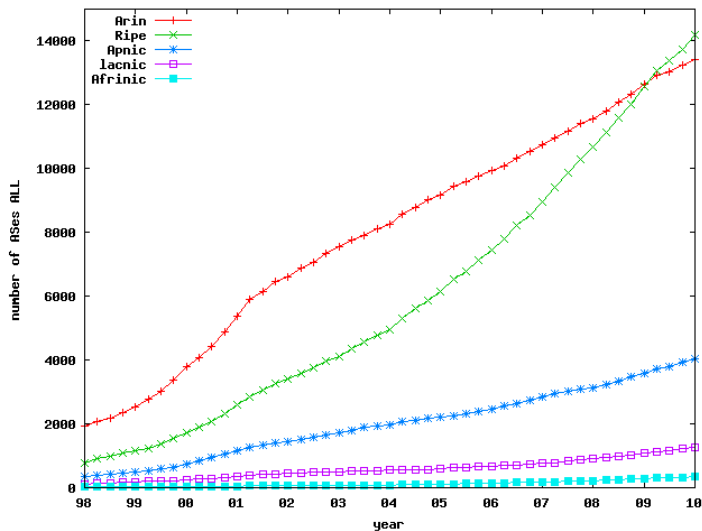




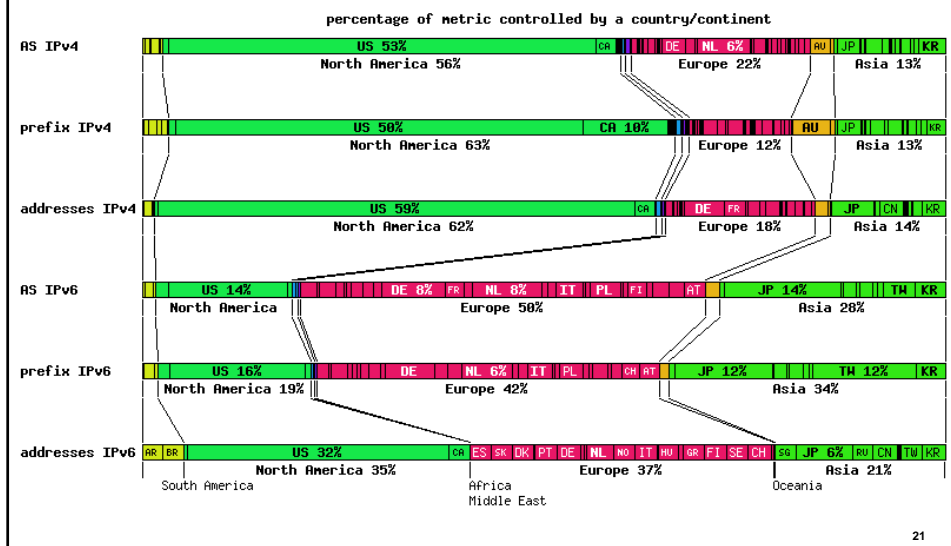


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## State of the states !

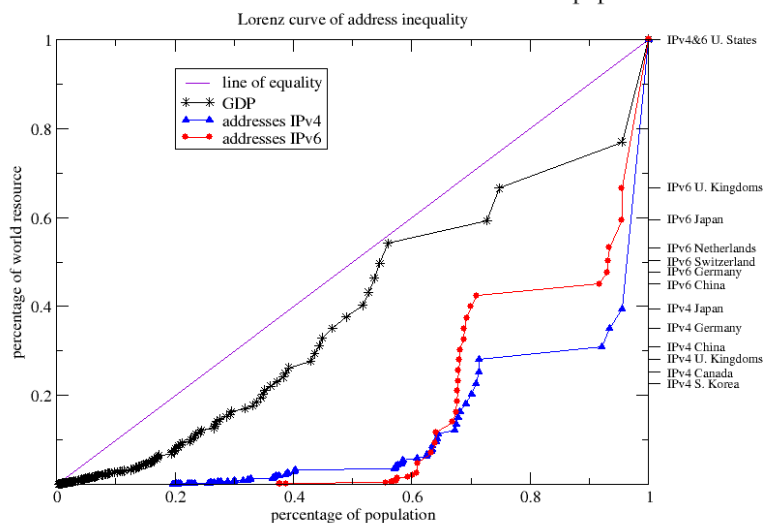


## State of IP addressing



## Are we in Fair state ?

distribution of GDP and IP addresses across the world population



## Future Internet Architecture

- What does an Internet Architecture hope to achieve?
  - Interoperability across networks, Easier for applications to code to , Framework for providers to compete
- What does an architecture do ?
  - Choose Paradigm
    - Packet/circuit/new(e.g. multihop radio)?
  - Fundamentally is net a “graph”?
  - Are protocols/services “layered”?
- Choose Functional Decomposition
  - Trade between packet header and node
  - Choose stateless or stateful (e2e v. hbh)
  - can do NAT, Header Compression and QoS/Flows)
  - Are nodes different (host v. router)?
  - Choose Packet Format(s)

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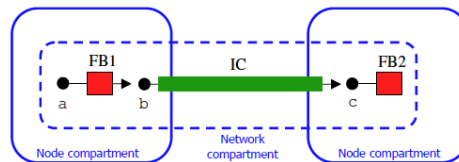
## What did Internet Architecture achieve?

- Interoperability:
  - No – not really
- Uniform API:
  - Bad thing: hides useful features of the underlying network.
    - eg. cross layer optimisations
- Provider framework:
  - Has any tier-1 ISP ever made significant profit from offering IP service?
    - Net Neutrality Debate etc.
- But ....
  - It used to enable rapid innovation
    - Claim: lack of attention to value flow & economics was a good thing!
  - High commercial value blunts innovation (c.f. other industries)
  - Disruption is bad for business
- ***Future Internet architecture should be tailored such that it enables surprising things***

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## IST ANA project Premises

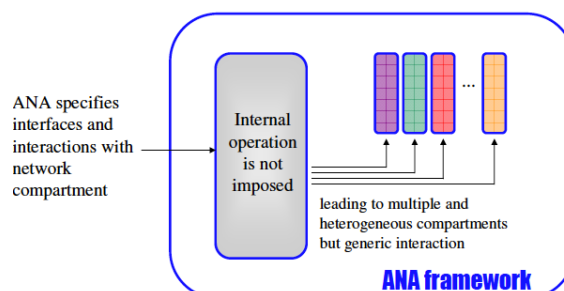
- Need to separate “mechanics” from “networking logic”
- Identify “universal” communication abstractions
  - An “Axiomatic Basis of Communication”
    - Stack becomes a tool box and framework
    - Populated by constantly changing protocol logic and autonomic steering logic (adaptivity, evolvability)
- Functional Block (FB): data processing entity
- Information Dispatch Point (IDP): indirection/start-points
- Compartments: “wrappers” for networks and admin domains. + “technology agnostic” communication API



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## IST ANA project proposed architecture

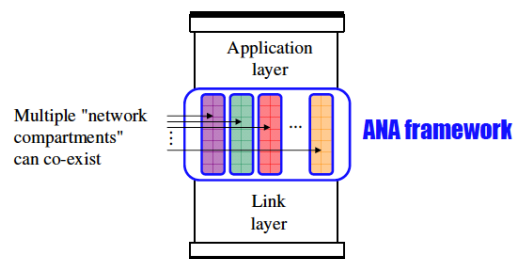
- A meta-architecture
  - That does not impose how network compartments should work
    - A framework to host, interconnect, and federate multiple heterogeneous networks.
  - Internally: the ANA framework specifies how networks interact.



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## Compartments

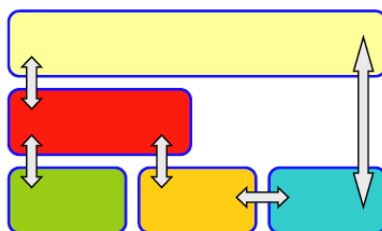
- A (network) compartment implements the operational rules and administrative policies for a given communication context. It defines:
  - How to join and leave a compartment: member registration, trust model, authentication, etc.
  - How to reach (communicate with) another member: peer resolution, addressing, routing, etc.
  - The compartment-wide policies: interaction rules with "external world", the compartment boundaries (administrative or technical), peerings with other compartments, etc.
  - Compartments decompose communication systems and networks into smaller and easier manageable units.



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## Compartment dynamic reconfiguration

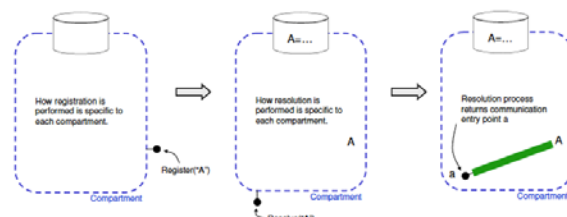
- The compartment abstraction serves as the unit for the federation of networks into global-scale communication systems.
- Compartments can be overlaid, i.e. compartments can use the communication services of other compartments .



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## Addressing and resolution

- Registration and resolution
  - Conceptually, each compartment maintains a membership database.
    - Registration: explicit membership is required ("default-off" model).
    - Resolution: explicit request before sending Addressing and naming are left to compartments.
- Each compartment is free to use any addressing and naming schemes (or is free to not use addresses)
  - No need to manage a unique global addressing scheme and impose a unique way to resolve names.
  - ANA is open to future addressing and naming schemes.
  - Global routing becomes something similar to searching.
    - if communicating parties are not all members of a given compartment.



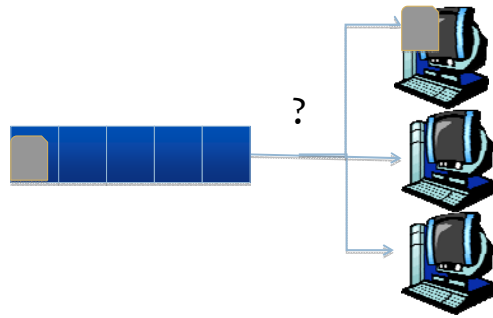
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## Prototyping

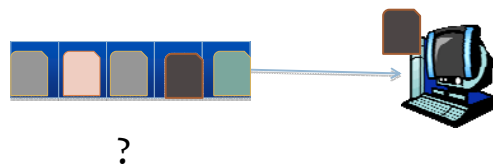
- Project has developed an ANA node prototype.
  - All functionalities of ANA + an abstraction layer to run ANA on different operating systems or on dedicated hardware (e.g. network processors).
  - The system is being ported to handheld devices like the Android, iPhone, Nokia N810, as well as NetFPGA and Network processors
  - A scripting facility (with Lua) for quick developments of components
  - More details at <http://www.ana-project.org/>

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## Classical forwarding



## New paradigm





## Why to forward ?

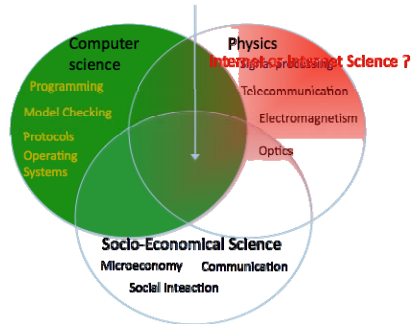


- Let's define for each packet a set of attributes  $A_i$ 
  - Destination address  $D(P_i)$
  - Some Attributes are extracted from packet, some are coming from local context
- Let's define a utility function  $U(A_i, D(P_i), ID, A)$ 
  - The utility of forwarding message  $i$  destined to  $D(P_i)$  to node  $ID$  with context  $A$
  - The utility function capture the selfishness of the node
- Forwarding scheme :
  - Calculate for each packet in buffer its utility
  - Forward the largest utility

## Utility functions

- Classical routing : Assign the utility function 1 if the node  $ID$  is on the path to destination  $D(P_i)$  null otherwise
- What if the utility doesn't depend on destination address ?
  - Results in epidemic forwarding
- Self Limiting Epidemic forwarding: The utility is scaled down everytime a packet is received or forwarded.
- Community or content networking :Give a higher utility to some contents or community.
- Each compartments can implement different utility functions !

## Toward a Science of networking



- Is Internet only a technology happening at the intersection of sciences or is it a science by itself ?
- What are its fundamental principles ?

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## Conclusions

- Architecture research is **philosophy**, not science or engineering
- The devil is in the details, so:
  - Let 1000 architectures bloom by providing a playground for it
  - World will pick a winner
- So be ready to adapt and be flexible !
- Networking is emerging as a science with underlying principles.
  - We need to build a science of Internet and put it on fundamental basis
  - A new economical theory is needed !

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## Future ???



"This just isn't doing it for me. Could we go back to using the crystal ball?"