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Novas Arquiteturas de Rede para a Internet do Futuro

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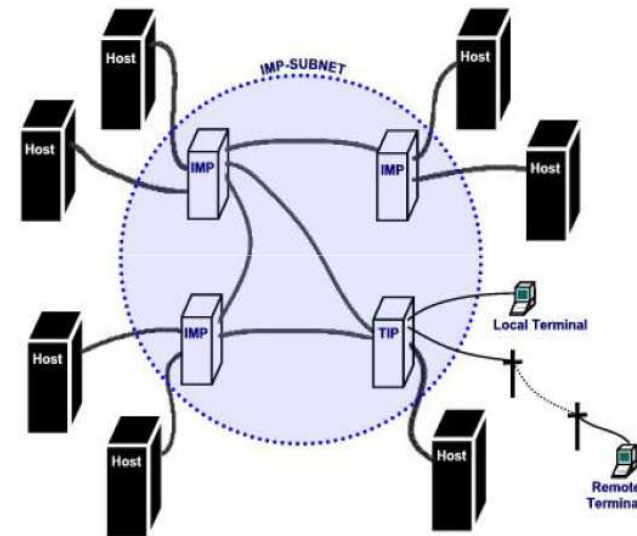
Data: 02/10/2009

Arquitetura de Rede

- Conjunto de **princípios** utilizados no projeto de protocolos e mecanismos para a comunicação entre computadores
 - **Como as entidades são nomeadas, endereçadas, roteadas, modularizadas em camadas, etc...**
- Representa um conjunto de escolhas dentre diversas alternativas de implementação
- Provê um **guia** para tomada de decisões técnicas no desenvolvimento de protocolos e algoritmos

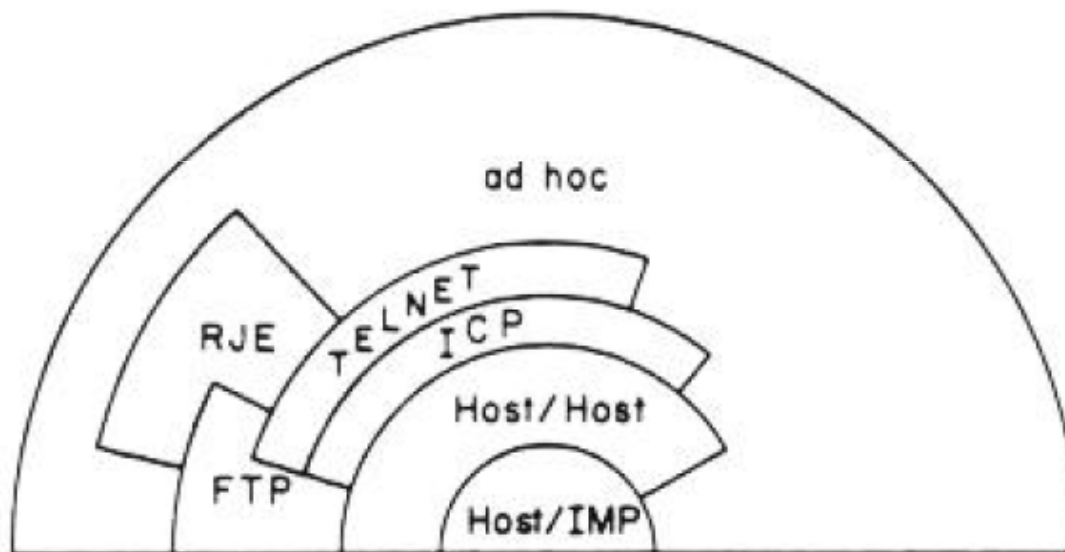
Origem da Internet - ARPAnet

- A arquitetura original da Internet foi projetada para conectar computadores e compartilhar recursos na década de 70
- A realidade atual e a mudança nos requisitos está inviabilizando a arquitetura original
- A coerência dos princípios está sendo perdida



Internet Original

- A arquitetura original foi projetada para algumas aplicações e serviços



Layered relationship of ARPANET protocols

IMP – Interface Message Processor

ICP – Initial Connection Protocol

Telnet – acesso de um terminal a um host

FTP – File Transfer Protocol

RJE – Remote Job Entry

Então, qual é o problema?

- Não há nada errado com o TCP/IP
 - “It is the problem that has changed!” [Van Jacobson 2006]
- A Internet foi concebida neste mundo:

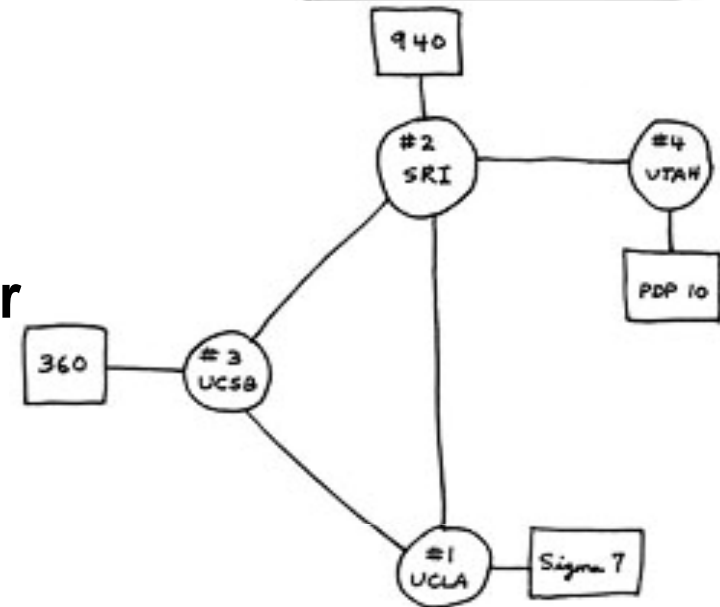


- Era para compartilhar recursos, não dados, e certamente não era para fazer negócios!!

O que mudou?

Internet Original

- Rede experimental para compartilhar recursos (impressoras, tapes) movendo pacotes entre um número limitado de máquinas conhecidas



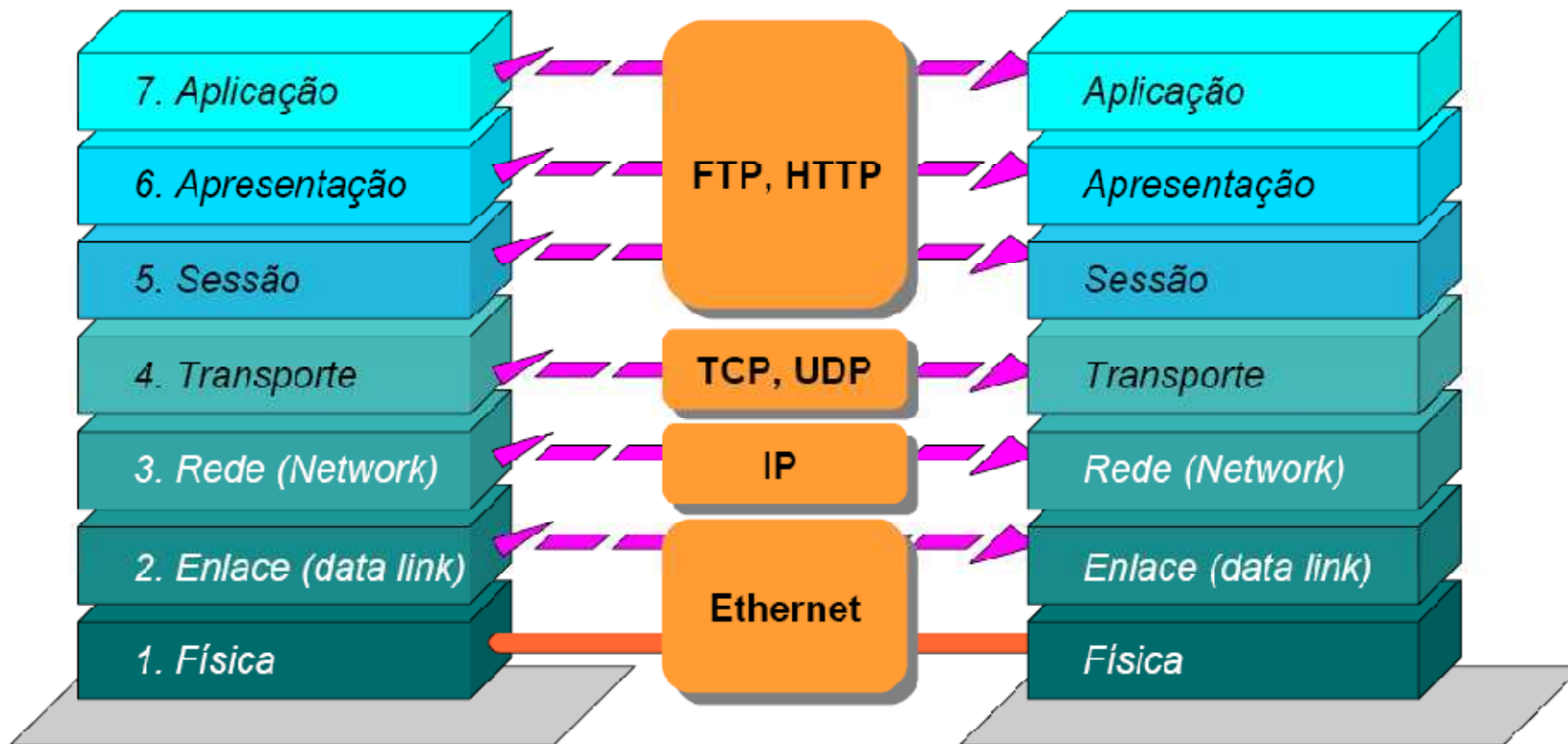
Hoje

- Internet é para mover dinheiro, mover pacotes é só uma consequência



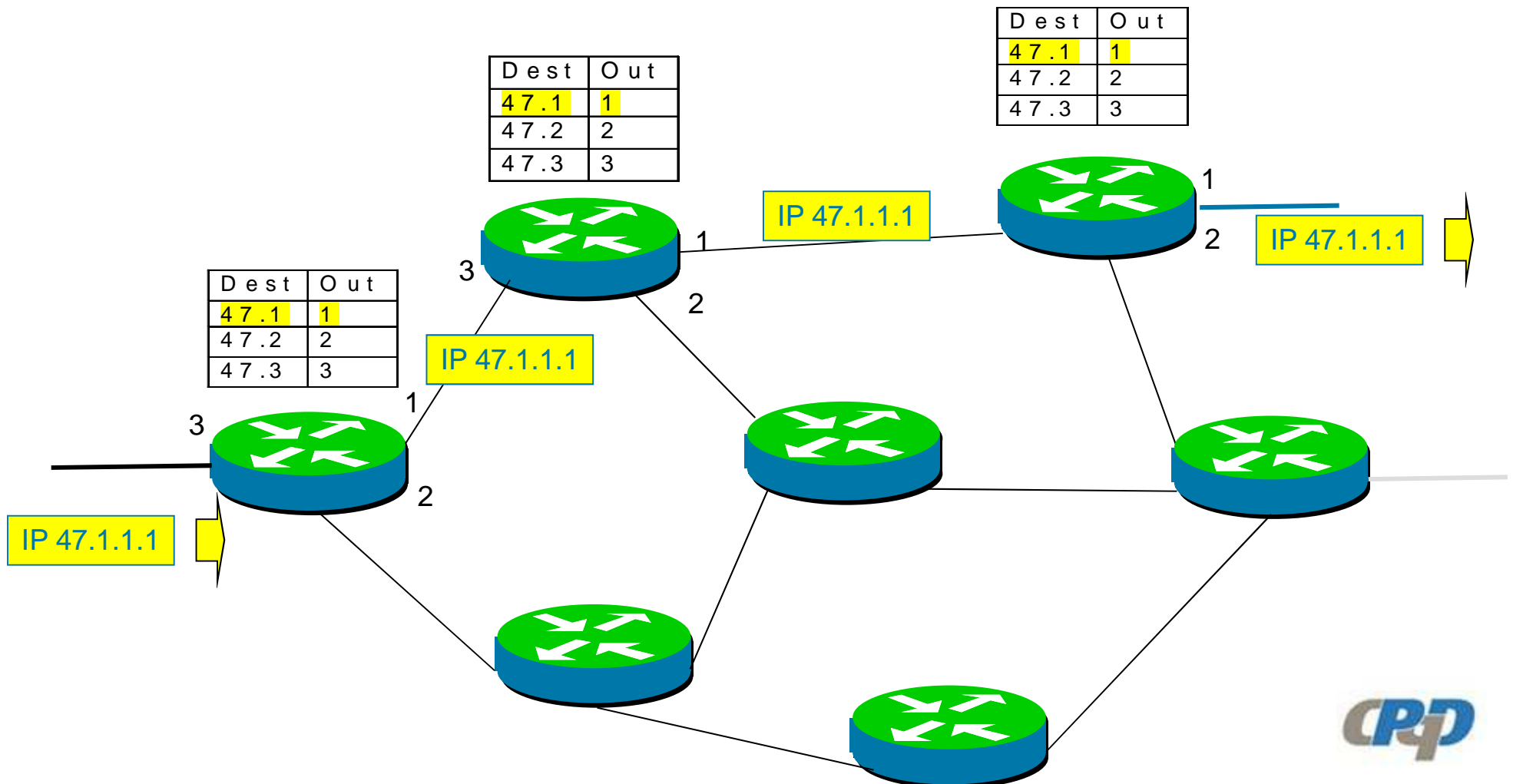
Princípios da Arquitetura da Internet

- 1) Modularidade em camadas



Princípios da Arquitetura da Internet

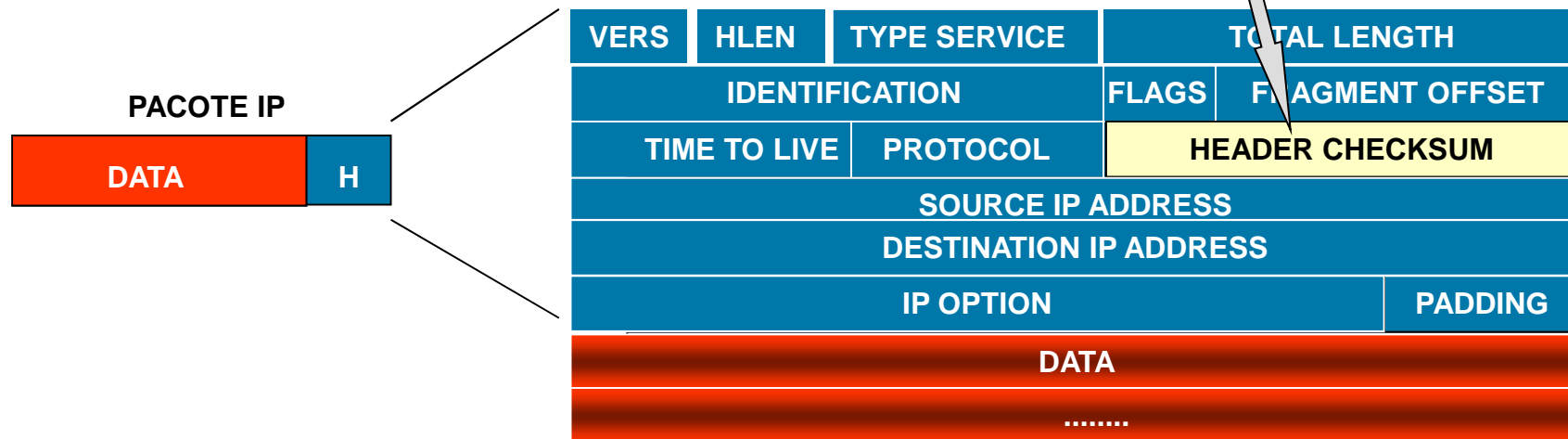
- 2) Encaminhamento de pacotes não orientada a conexão (“dumb network”)



Princípios da Arquitetura da Internet

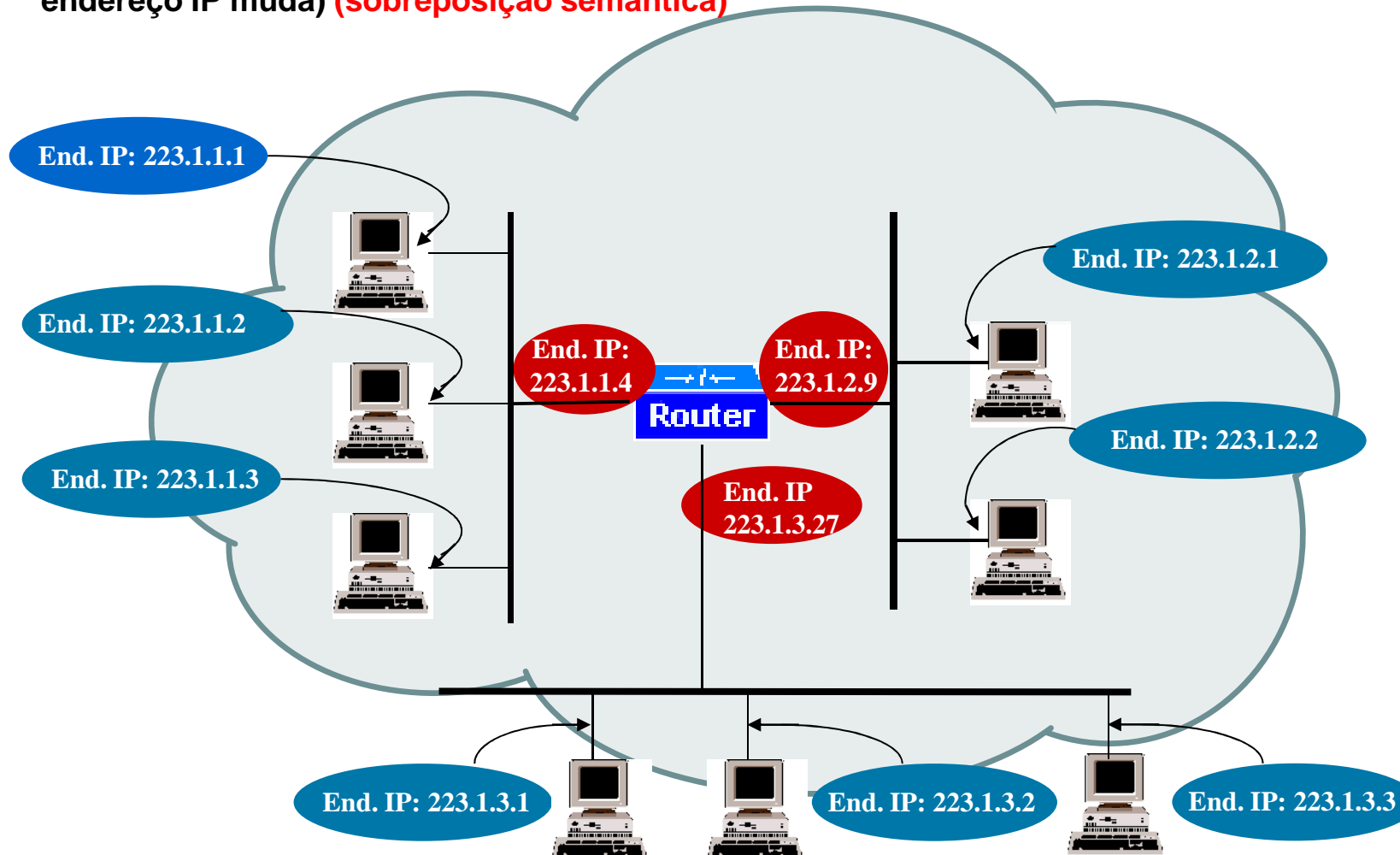
- 3) *Internet Protocol (IP)* não provê comunicação segura:

- Não há confirmação de recebimento (“acknowledgements”)
- Sem controle de erros nos dados, apenas “*header checksum*”;
- Não há retransmissão de dados;
- Não há controle de fluxo.



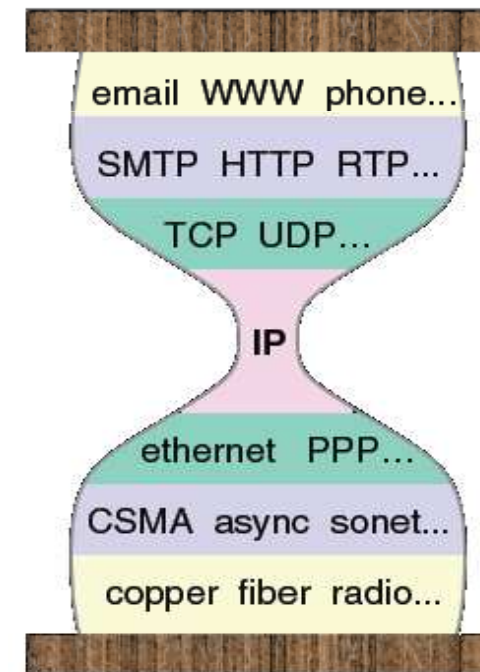
Princípios da Arquitetura da Internet

- 4) Endereços aplicados às interfaces físicas dos roteadores e hosts são utilizados tanto para o roteamento quanto para nomear a interface (se o roteador ou host muda de localização física, o endereço IP muda) (**sobreposição semântica**)



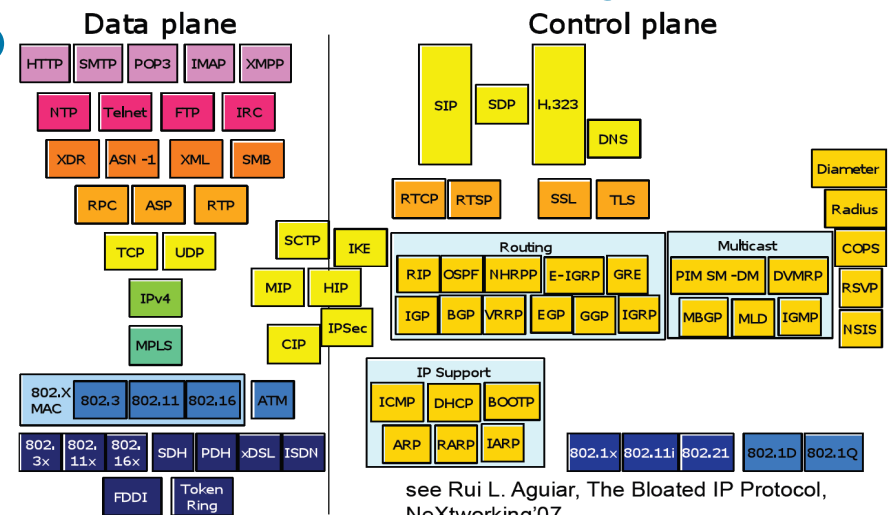
Por que sobreviveu?

- **Internet é um grande sucesso!**
 - **Acabou substituindo várias tecnologias de rede**
- **Usuário final adotou a tecnologia**
 - **Simplicidade**
 - **Transparência**
 - **Modelo da Ampulheta**
 - IP sobre tudo
 - Tudo sobre IP



Como tem sobrevivido?

- Com muitas extensões e modificações na arquitetura
 - Extensões em mobilidade (ainda falhas)
 - Extensões em segurança e proteção (ainda pobres)
 - NAT (Network Address Translator)(característica boa ou ruim?) (*Carrier-Grade NAT*)
- ... e uma série de protocolos de controle e sinalização para manter tudo funcionando

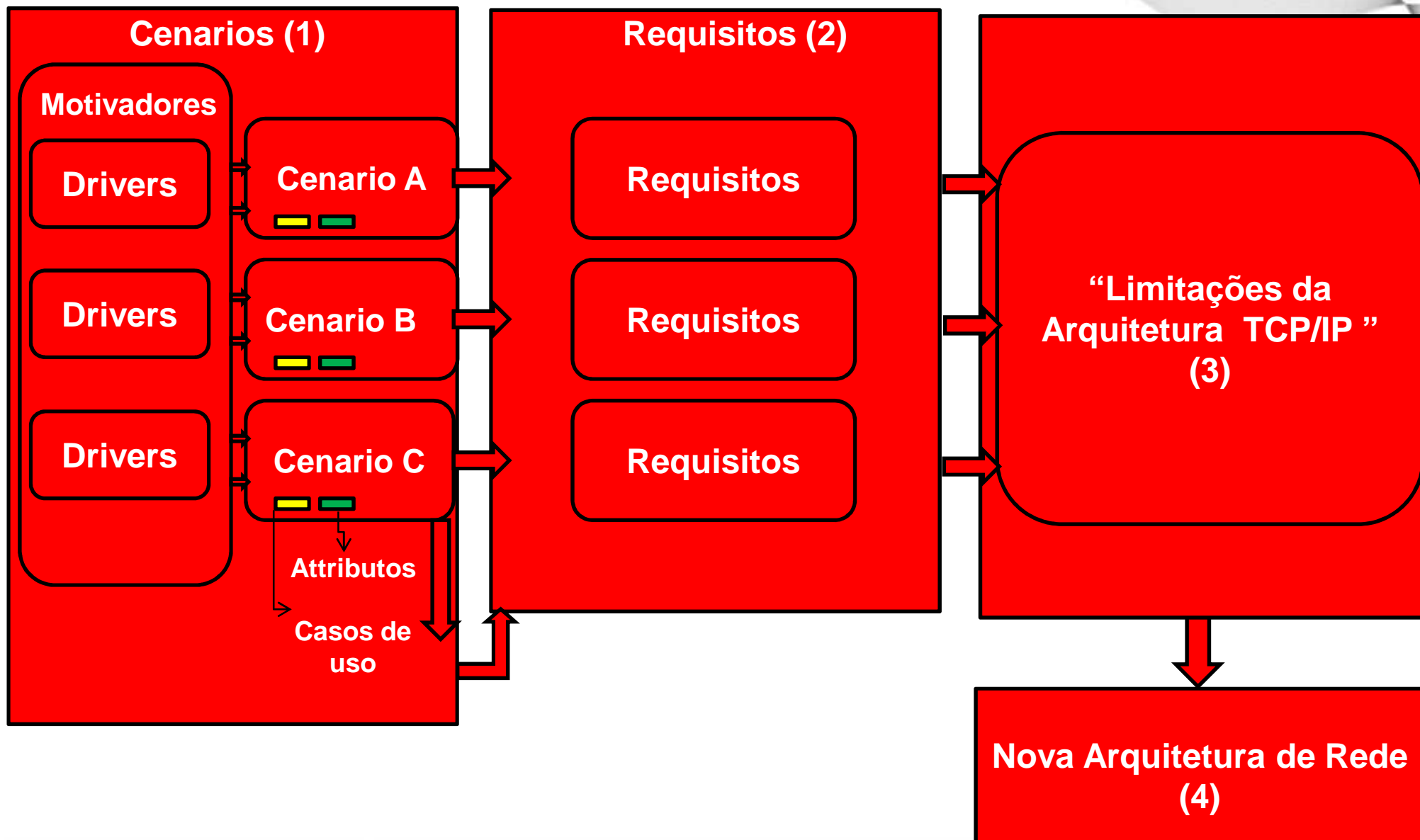


O que mudou?

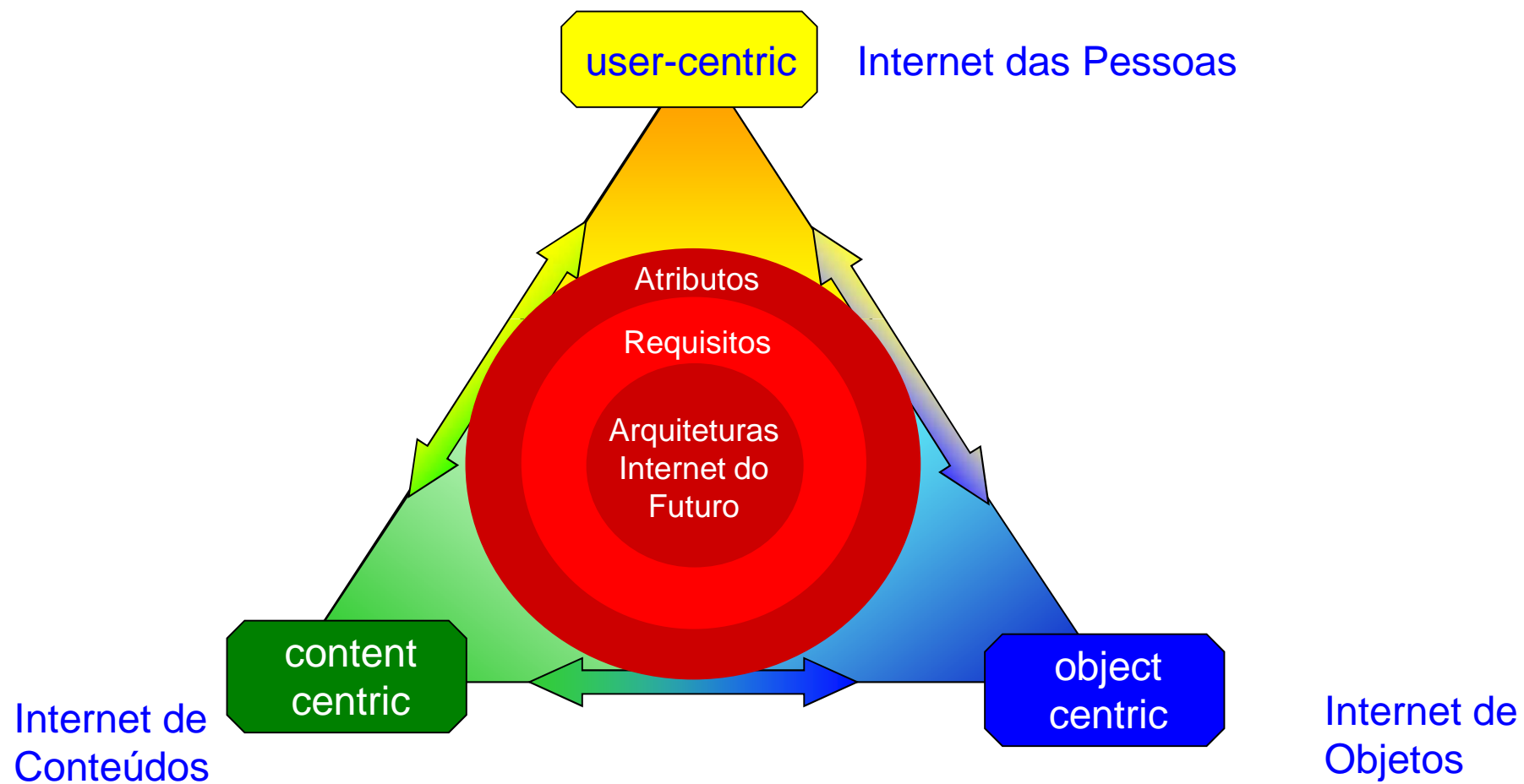
- **A Internet foi projetada**
 - Para hosts fixos
 - Operar de forma cooperativa num ambiente seguro
 - Ser altamente escalável (dentro da realidade dos anos 80)
 - Com endereçamento fim-a-fim
 - Centrada nos dispositivos terminais
- **Hoje**
 - Muitos terminais são móveis
 - Roubos e crimes na rede
 - Explosão da tabela de roteamento e endereçamento
 - Endereçamento fim-a-fim tornou-se quase uma exceção
 - Centrada na informação
- **Nenhum destes princípios se aplicam atualmente**
- **Tecnologia não é a melhor, mas funciona!**

Projeto de Uma Nova Arquitetura – Abordagem “Top-Down”

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Cenários de Evolução da Rede



Cenário Focado nas Pessoas (User-Centric)

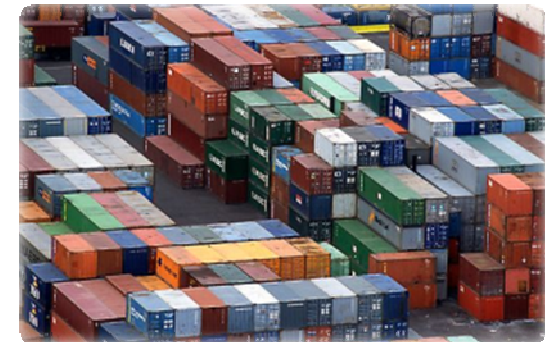
- Provê um portfólio de serviços personalizados e ubíquos às pessoas
 - Internet dos Serviços
- Os principais atributos deste cenário são:
 - Mobilidade e Ubiquidade
 - Controle do usuário
 - Rede Dinâmica
 - “Context-awareness”
 - Auto-configuração
 - Multi-homing
 - Segurança e privacidade
 - Gerência de identidade



Source: <http://mysite.pratt.edu/~giannini/lis628b.html>

Cenário com Foco no Conteúdo

- Disseminação de “*named pieces of data*”
- Content Centric Network - Van Jacobson
 - “Transform the network from a “link-structure” to a “network of information”
- Os principais atributos deste cenário são:
 - Criação e disseminação eficiente de conteúdo digital
 - Identidade de itens de informação
 - Novos algoritmos de roteamento para conteúdo
 - Rede centrada no receptor da informação (por exemplo, publish / subscribe)
 - Novos mecanismos de caching and replication
 - Localização e busca de objetos de informação
 - Multicast, anycast e multipath information flows
 - Segurança e privacidade



Cenário com Foco nos Objetos

- Provê conectividade ampla de dispositivos e sensores à Internet

“Internet of Things”

- Os principais atributos deste cenário são:
 - Identificação de objetos móveis e ubíquos
 - Interação entre objetos (“smart objects”)
 - Crescimento de robôs e máquinas no ambiente doméstico
 - Aumento do tráfego em tempo real para controle dos objetos
 - Segurança e privacidade da informação de controle dos objetos



Atributos dos Cenários – Exemplos

Atributos	Internet de Pessoas*	Internet de Conteúdo	Internet de Objetos
Mobilidade, Ubiquidade	Serviços baseados em localização; hand-off em IP	Localização do conteúdo, não do servidor (IP)	Roteamento em redes de sensores móveis
Capacidade, confiabilidade, disponibilidade	Serviços críticos; banda larga, ...	Otimização da composição do tráfego (P2P), ...	Bilhões de objetos; protocolo eficiente em energia
Segurança e Privacidade	Novo modelo de rede, na qual a segurança seja intrínseca?	Direitos autorais, ...	Objetos são “burros”; Posso confiar “nesse objeto”?

* inclui requisitos da Internet de Serviços



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Why and how research on Future Internet?

INTERNATIONAL EFFORTS TOWARDS THE FUTURE INTERNET

What happened with the All-IP dream?

- **Wait a minute, a few years ago all was about IP convergence ...**
 - **see SBRT 0X, SBRC 0X, etc.**
- **Now that the Telecom world has adopted IP, we don't want IP anymore?**
 - **IP is not good, it does not scale, security, etc.**
- **We are researchers,**
 - **our job is to question paradigms**
 - **our job is to start the debate on a post-IP scenario**
- **Besides the researcher's duty, there is a lot of rationale behind re-thinking the Internet architecture**

Issues

Experienced by User

- Security
- Reliability and QoE

Attackers

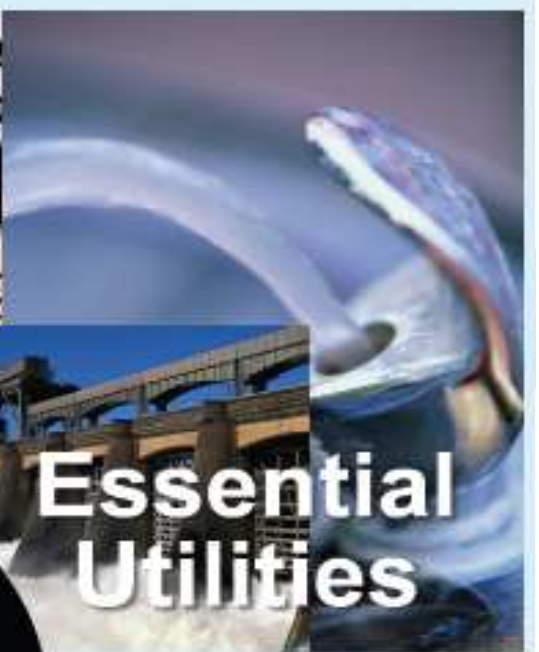
- Denial of Service
- Intrusion, Session Capturing, Phishing
- Worms, Viruses, Spammers

Pain for the operators

- Limited Address Space
- Mobility
- Multi-homing
- Routing table explosion
- Scalable management
- Too much P2P traffic?
- Business model with over-the-top services?



Transportation



Essential Utilities

People doubt that the Internet is robust enough to support these



Government Services



Telecommunications Banking & Finance



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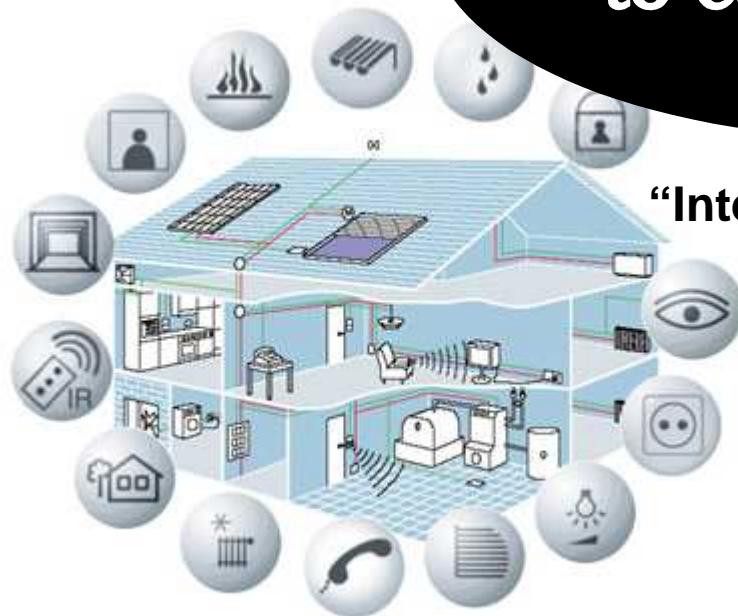


The (critical) Cloud

**More challenges
to come ...**



Global warming / cost of energy



“Internet of Things”

From user-generated content
to user-provided services

Everything mobile



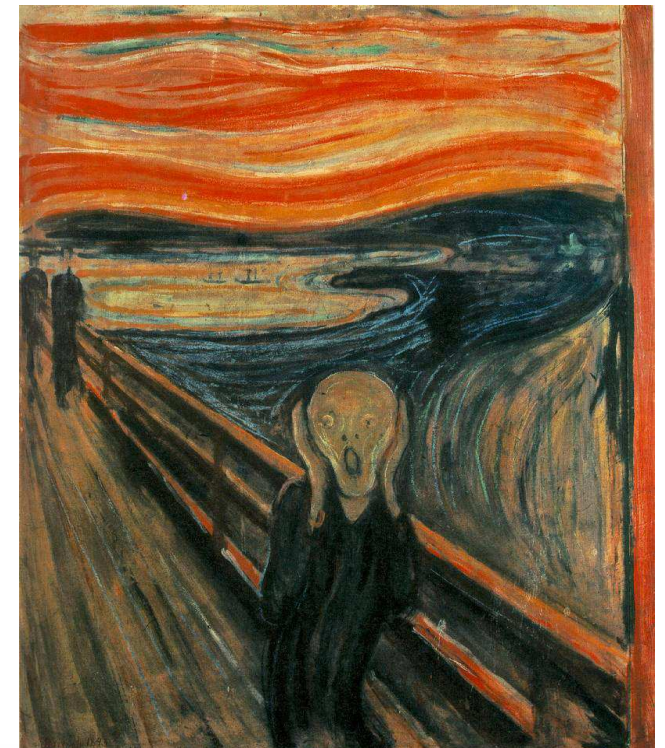
Why the research boom on Future Internet?

- **There is a big momentum on Future Internet research**
- **The Internet has invaded most aspects of life and society**
 - **Changing life, work, communication, social interaction, ...**
- **It brings many benefits but also threats**
 - **Governments are concerned about it (critical infrastructures... e-war, cybercrime)**
 - **Funding Internet research is considered one important contribution to dealing with the situation**

“The Internet Is Broken”

“The Internet will Collapse”

“The Internet Is Ossified”



So, what?

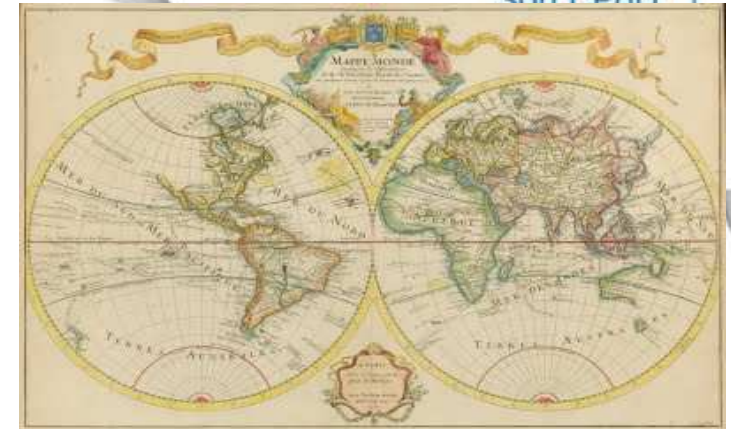
- **There is a common consensus that the Internet needs improvement**
- **There is no shared vision on how this may happen**
 - Not even a rough direction can be outlined
 - Popular (misleading) discussion item: *incremental or clean slate?*
- **Consequence:**

Let's do a broad search instead of intensive research

- **US: FIND initiative plus GENI building a big playground**
- **EU: funding many projects with different approaches**

Future Internet research projects popping up everywhere

- **GENI/FIND, USA**
- **Future Internet Cluster, EU**
- **New Generation Network / AKARI, Japan**
- **Future Internet Forum, Korea**
- **CNGI, China Next Generation Internet Project**
- **RNRT, France**
- **G-Lab Initiative, Germany**
- **SHOK, Finland**
- **Ambient Sweden Initiative, Sweden**
- **Internet del Futuro, Spain**
- **CANARIE, Canada**
- ...



Big momentum on Future Internet research

**We may have only one bullet,
so we better use it right!**



What do we need?

1. We need **visions** for the Future Internet
 - Re-thinking fundamentals (transport, routing, addressing, identity, new Internet waist)
 - Defining goals and requirements for the FI
2. We need **experimentally-driven** research for validation at scale and under realistic scenarios
 - E.g., GENI, FIRE, Federica, OneLab
3. We need **business** incentives for adoption
 - Think IPv6, MobileIP, IP Multicast, etc.
 - EIFELL, MIT CFP, BIRD, socio-economics market evaluations, Industrial engagement, etc.



Visions through Clean Slate Designs

1.- “With what we know today, if we were to start again with a clean slate, how would we design a global communications infrastructure?”

2.- “How should the Internet look in 15 years?”

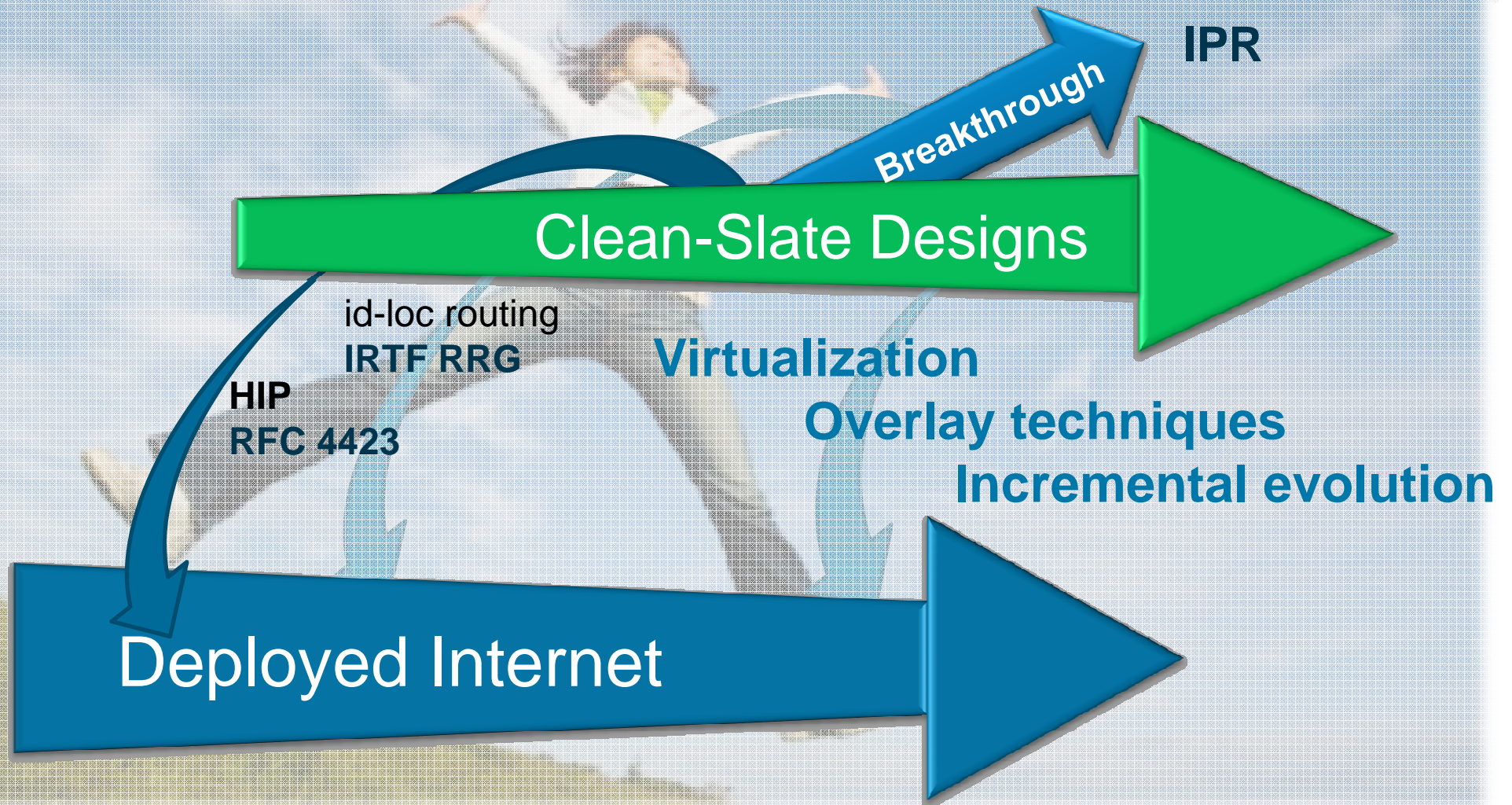
Disclaimer Notice:

Clean slate design does not presume clean slate deployment.

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- Late binding to reality -



Approaches and (visionary) ideas

- **There are many ideas out there,**
 - Some are already several years old
 - Few are fundamentally new
- **On the following slides some will be presented**
 - Subjective selection based on potential of networking revolution
- **Credits and references:**
 - D. Clark, “Moving FIND to the next stage”, Jul. 2009
 - <http://groups.csail.mit.edu/ana/People/DDC/Working%20Papers.html>
 - V. Jacobson, “Networking Named Content” to appear at CoNEXT 2009
<http://www.ccnx.org>
 - EU FP7 PSIRP – Publish Subscribe Internet Routing Paradigm,
<http://psirp.org>
 - J. Quittek, “The Future Internet, Is it time to look for a new one?”

Approaches and (visionary) ideas

- Overlay networks
- Network virtualization
- Software-defined networking **[OpenFlow]**
- Locator-identifier split
- Information-oriented networking **[CCN, PSIRP]**
- New control architectures
- Self-management
- Revisiting networking fundamentals
 - **What defines an architecture? There is no networking science.**
 - **Addressing, Routing, Security, Management, Availability**
[D.Clark]
- **Many more....**

Multiplexing - a basic issue

- **Old (1960's) idea: packets.**
 - Seems to have worked out well.
- **New ideas:**
 - **integrated management of packets and circuits (aggregates).**
 - Integrated management.
 - Fault recovery, routing/traffic engineering.
 - Integrate future concepts in optics (routing vs. TE)
 - **Virtualization of routers and links**
 - Avoid need to have one design.
 - Needs assessment and practical validation

Routing

- **Old view:**
 - Find the lowest cost route
 - Load-based dynamics lead to instability.
- **New ideas:**
 - Random route selection (oblivious routing avoids link DoS and TE)
 - User route selection (P2P, Multi-homing)
 - Multi-path routing. (TCP multipath, IETF, Trilogy)
 - Energy/cost-aware routing (SIGCOMM 09)
 - Machine learning to achieve high-level policies (self-optimization)
 - Move route computation out of forwarders (4D, OpenFlow)
 - Multiple simultaneous routing schemes (virtual network slices)
 - ID-loc separation (HIP, LISP)
 - Routing on flat identifiers (Pasquini et al.)

Connection establishment

- **Old idea:**
 - minimize the round trips.
- **New ideas:**
 - **Need a phase for exchange of identity.**
 - May need a “cross-layer” initial exchange.
 - Re-modularize TCP to be less layered.
 - **Need to diffuse attacks.**
 - Adding a round trip or two (esp. if not always) worth the cost in order to allow an E2E (identity) check.
 - Part of availability framework.
 - **Fit this thinking into the DTN paradigm.**

Addressing

- **Old view:**
 - **Designed for efficient forwarding.**
- **New view: take into account**
 - **Security issues**
 - Accountability, privacy, deterrence, hiding.
 - **Management issues**
 - Re-numbering
 - **Multi-homing**
 - **Do you really want to address physical nodes?**
 - How about services? Information? Anycast?
 - But consider lower-layer management issues.

Application design

- **Old view (simplistic): our machines talk.**
 - Host-to-host conversation
- **New view:**
 - Lots of servers and services (resource pooling in cloud DCs)
 - Need for cross-application core services
 - Identity management, social networks
 - Modulate behavior based on trust.
 - Name-oriented socket API [cf. C. Vogt]
 - Linked Data (cf. Semantic web)
- **Application design patterns and building blocks should be part of the future network.**

Information-layer

- **Old idea: an application issue (ignore it.)**
- **New idea: need a framework**
 - **Naming and identity of information.**
 - Independent of how you get it.
 - **Dissemination**
 - Swarms, P2P: (heterogeneous).
 - Improves availability of information if information is pushed into the network.
 - **Economics: one service or many competing?**
 - Competitive info dissemination “on top of” lower-layer transport.
 - **Information-Centric Networking**
 - Can we create a network architecture based on naming data instead of naming hosts?

Re-Architecting the Internet

- Information-centric approaches -

information-centrism

DONA

PSIRP

content-centric networking

New ID spaces

TRIAD

ROFL

id-loc

CDN

clean-slate

3

Interconnecting information

DPI

P2P

overlays

IPv6

NAT

middleboxes

patching

TCP/IP

networking (r)evolution

2

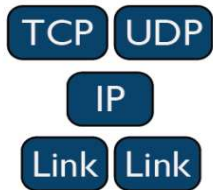
Interconnecting hosts

Telephony

1

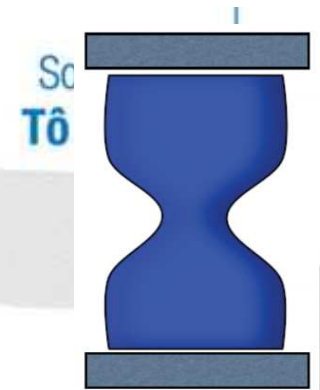
Interconnecting wires





Information-centric Networking

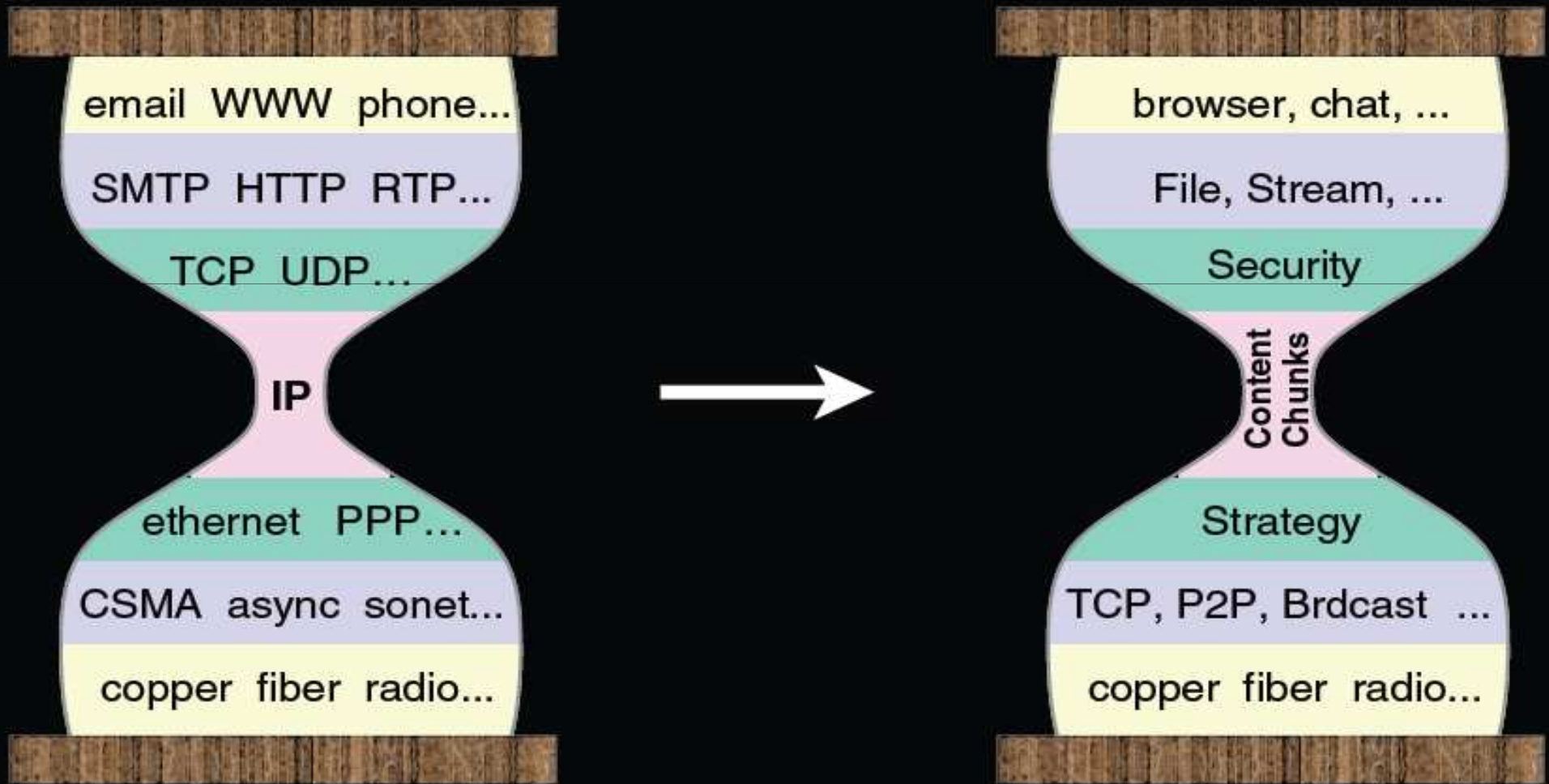
- Rethinking fundamentals -



- **Send / Receive** → **Publish / Subscribe**
- **Sender-driven** → **Receiver-driven**
- **Host names** → **Data names**
- **Host reachability** → **Information scoping**
- **Channel security** → **Self-certified metadata**
- **Unicast** → **Multicast**



CCN: A New Layering



What's in a Name (user/app view)

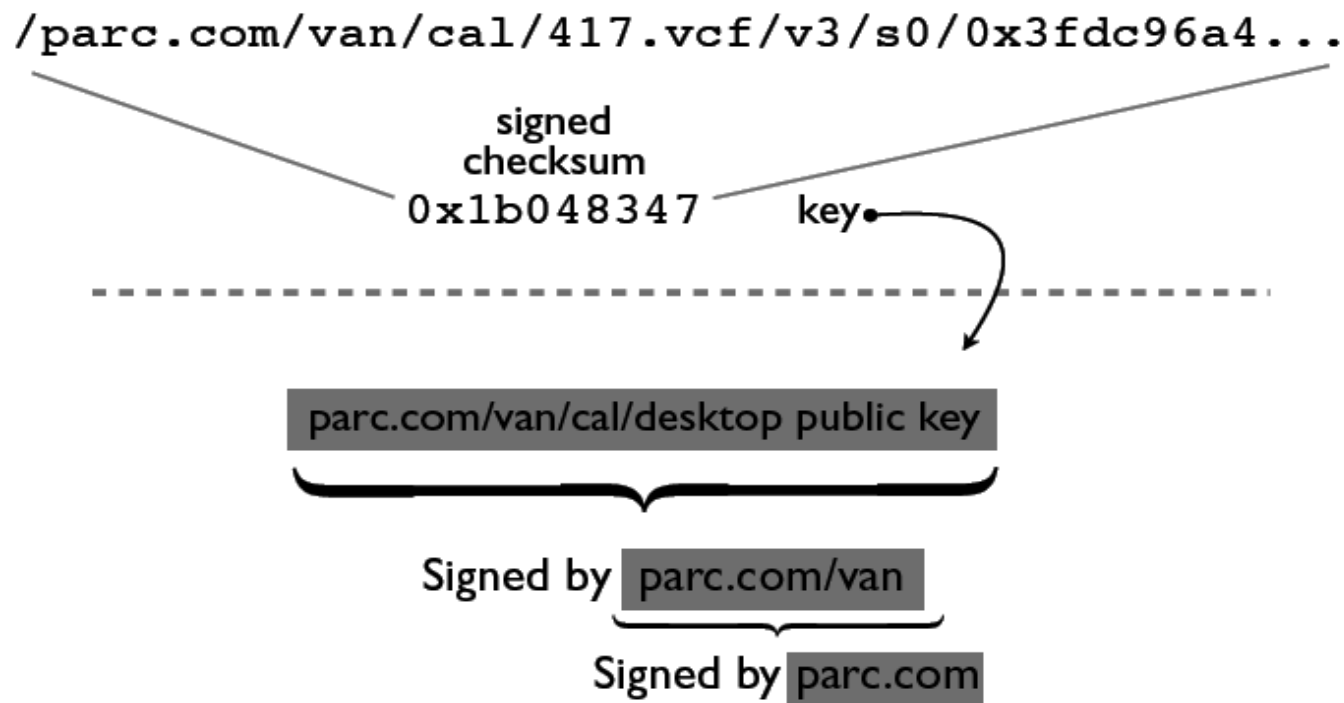
App supplied name Versioning & segmentation Content or proxy
(e.g., SHA256 checksum)

`/parc.com/van/cal/417.vcf/v3/s0/0x3fdc96a4...`

- Note that this binding is *immutable*
 - the data associated with the name can't change

Built-in security through self-certified data

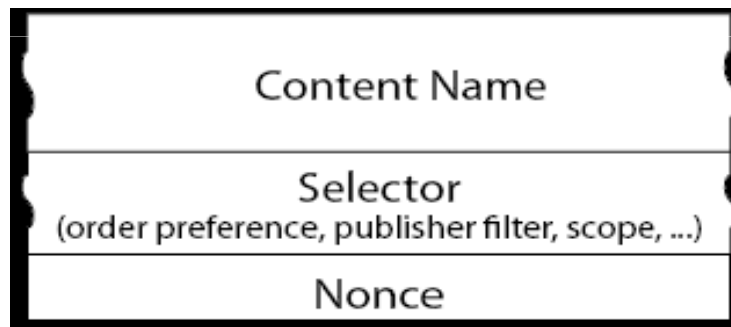
- Metadata contains encrypted cryptographic checksum and locator for the public key of the producer.
- Producer's key is typically hierarchically structured.



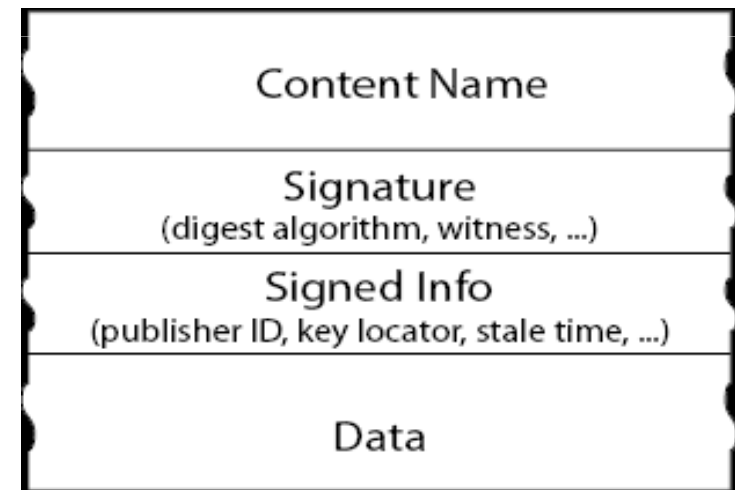
Two basic primitives

- There are just two CCN packet types -
interest (similar to “http get” or “subscribe”)
data (similar to “http response” or “publish”).

Interest packet



Data packet



Human Readable:

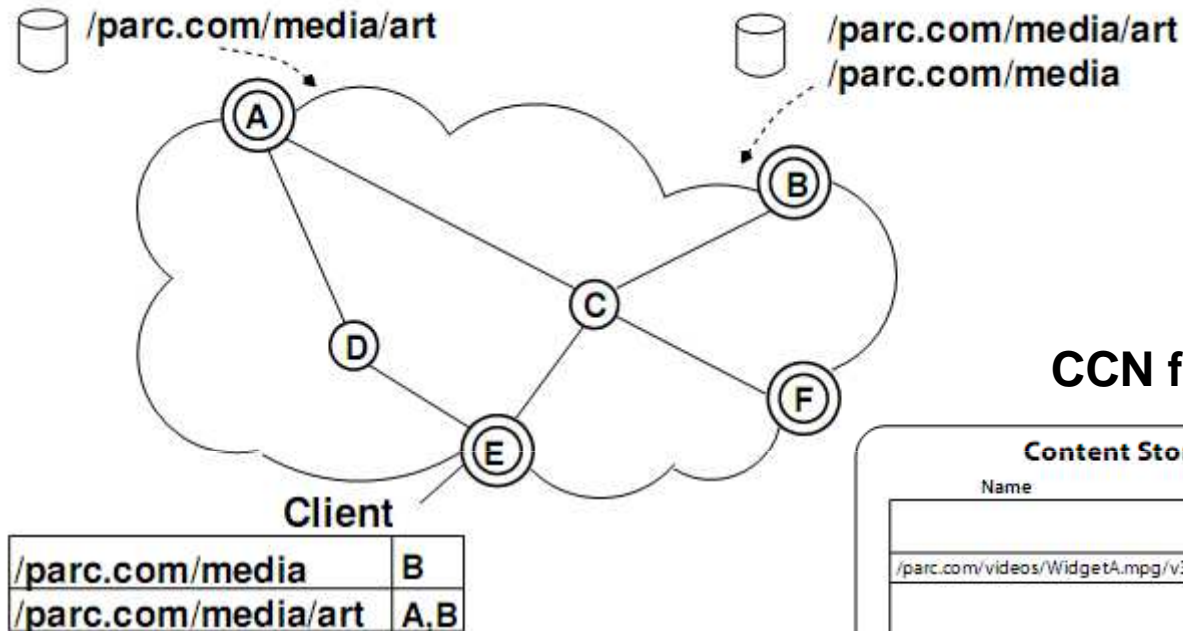
User/App supplied name		Versioning & Segmentation	
/parc.com/videos/WidgetA.mpg/_v <timestamp>/_s3			
Globally-routable name	Organizational name	Conventional/automatic name	

Binary Encoding:

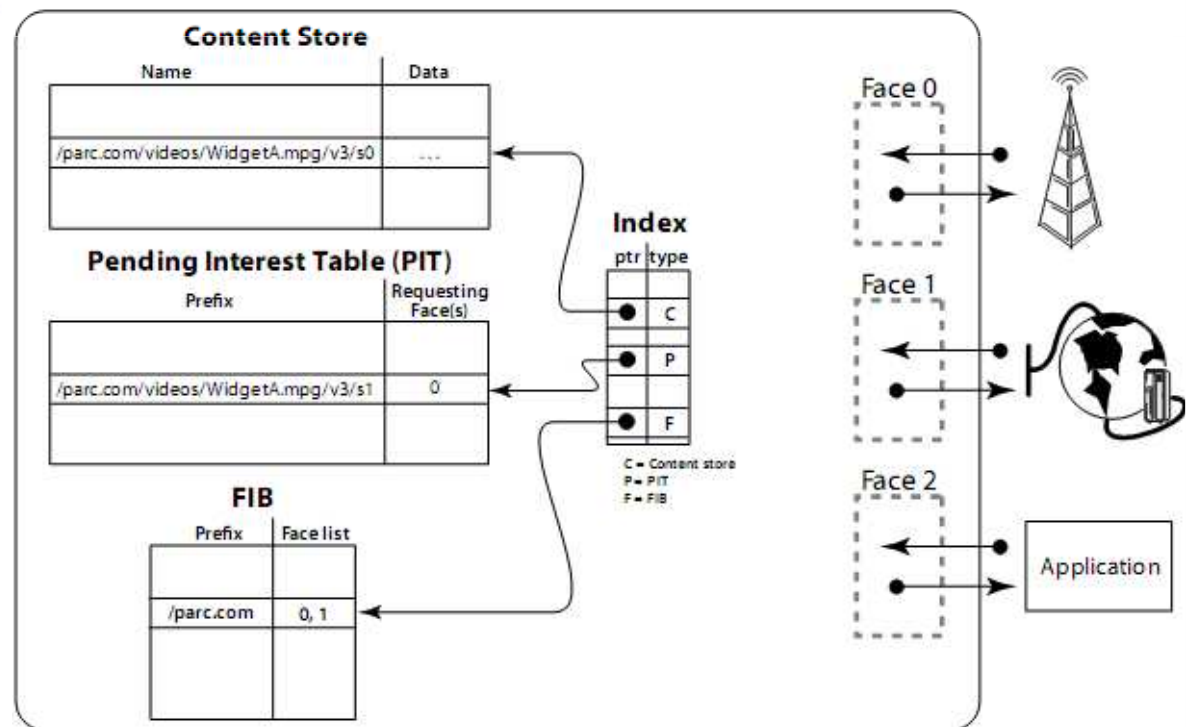
6	8	parc.com	6	videos	11	WidgetA.mpg	7	FD04A...	2	F83
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Content name

Name-oriented routing and forwarding



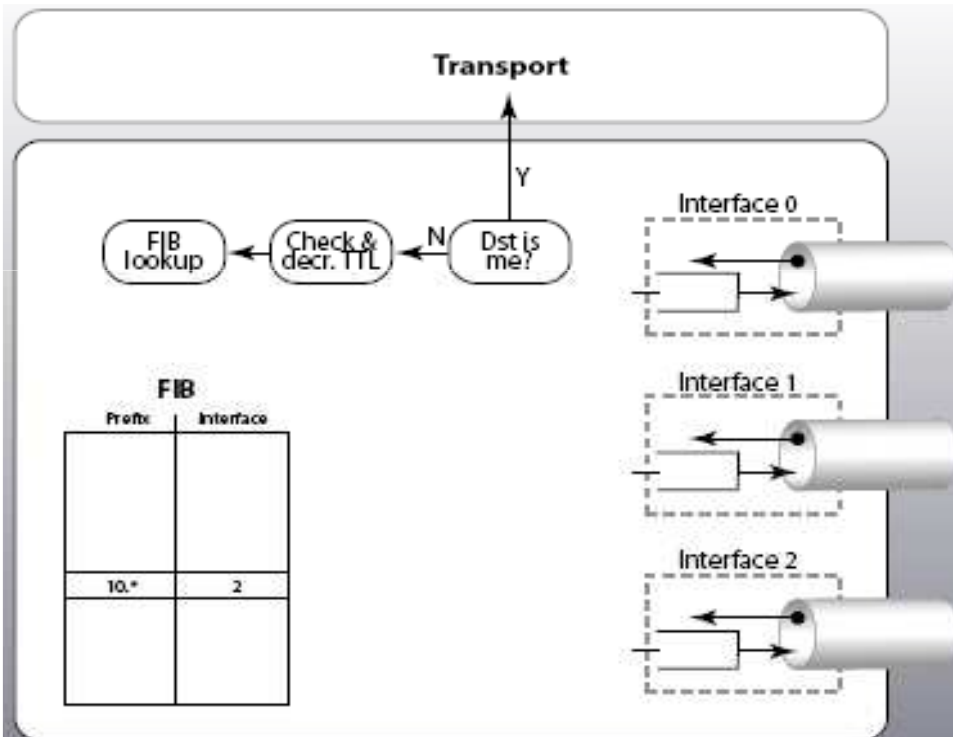
CCN forwarding engine model



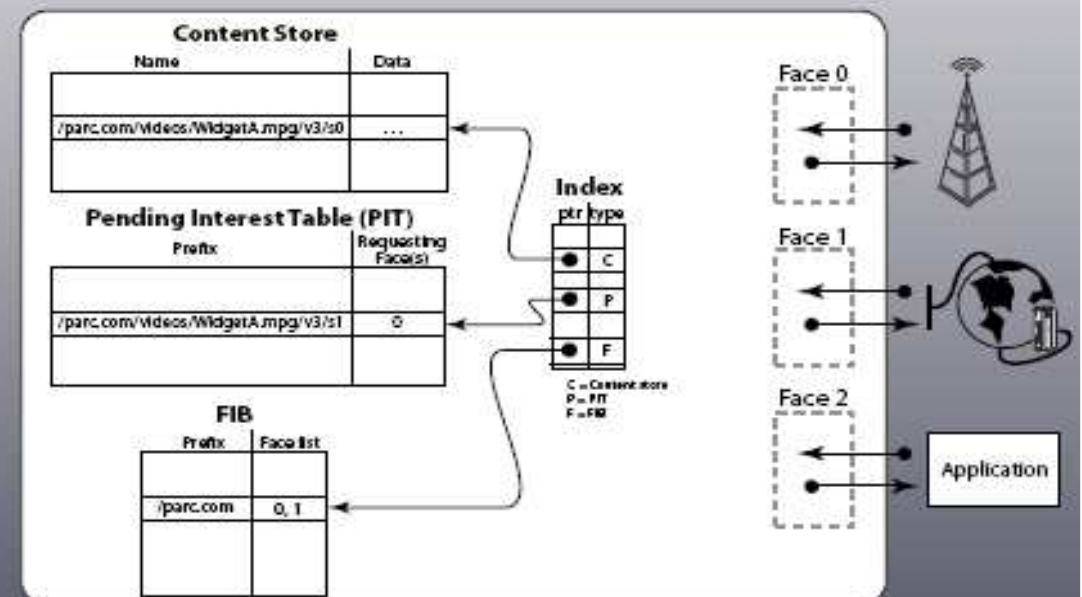
- FIB populates based on name aggr.
- **Interests** go to pending interest table and is forwarded based on the FIB
- **Data** packets remove PIT entries
- Content Store are opportunistic caches
- Flow-balance and loop-free

At a minimum, same hardware req. as IP

IP networking



Content-Centric Networking

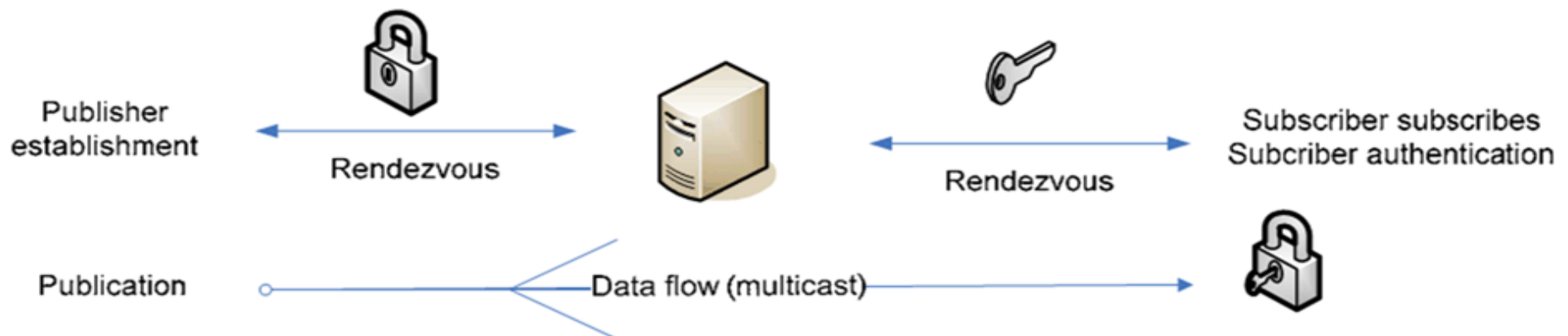


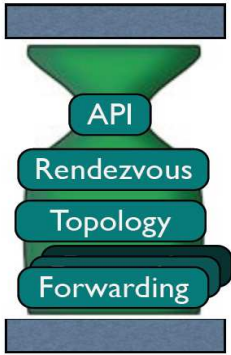
EU FP7 PSIRP Project



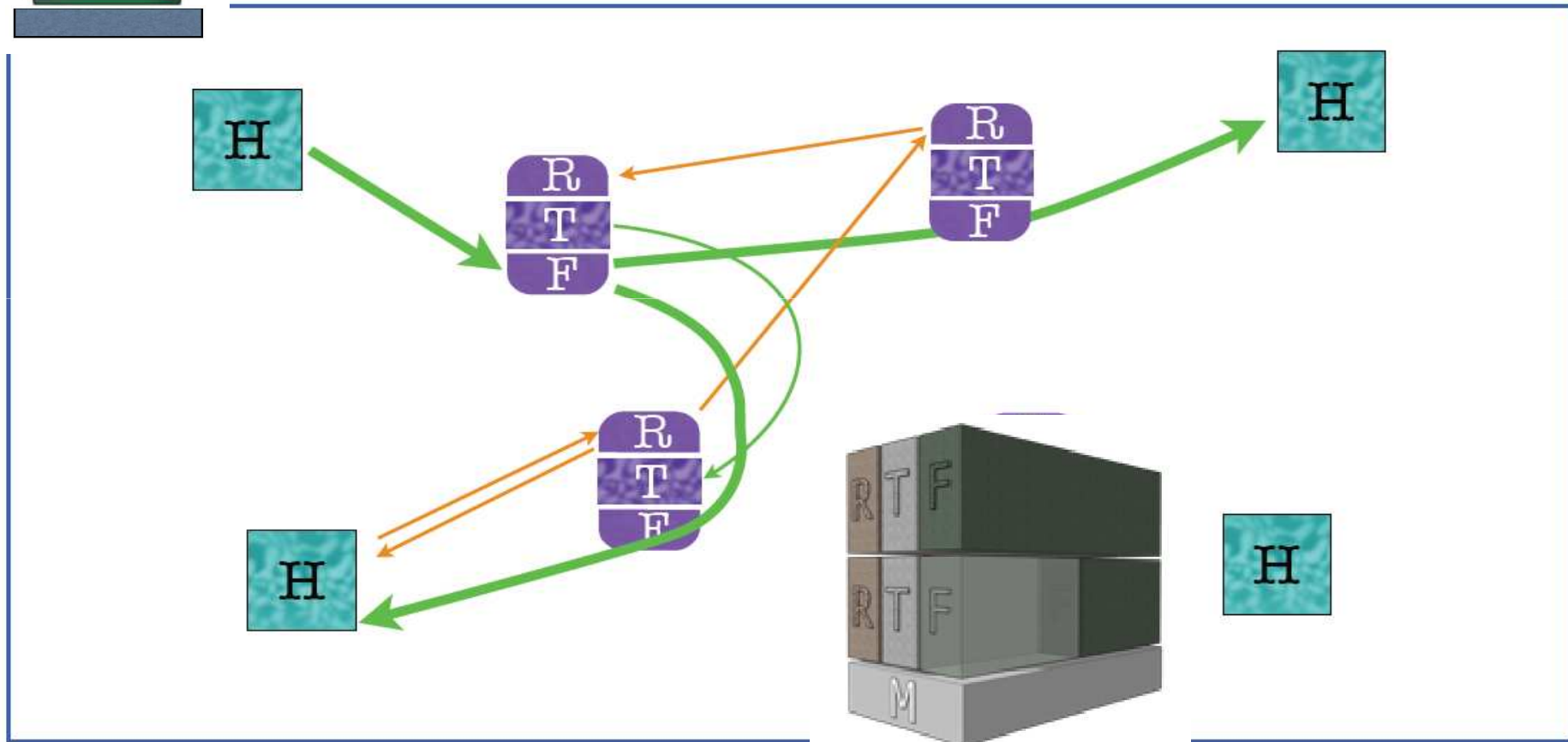
PSIRP
PUBLISH-SUBSCRIBE
INTERNET ROUTING
PARADIGM

- Redesign the Internet architecture from the pub/sub point of view, taking nothing (not even IP) for granted.
 - *Make “information” the centre of attention*
 - *Remove the “location-identity split” that plagues current networks*
 - *Innovative multicasting and caching features to optimize performance and efficiency*
 - *Security functionality as a native core component of the architecture*





PSIRP
PUBLISH-SUBSCRIBE
INTERNET ROUTING
PARADIGM



Software-defined networking with OpenFlow

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Control Path (Software)

Data Path (Hardware)

OpenFlow Controller

OpenFlow Protocol (SSL)



Control Path

OpenFlow

Data Path (Hardware)

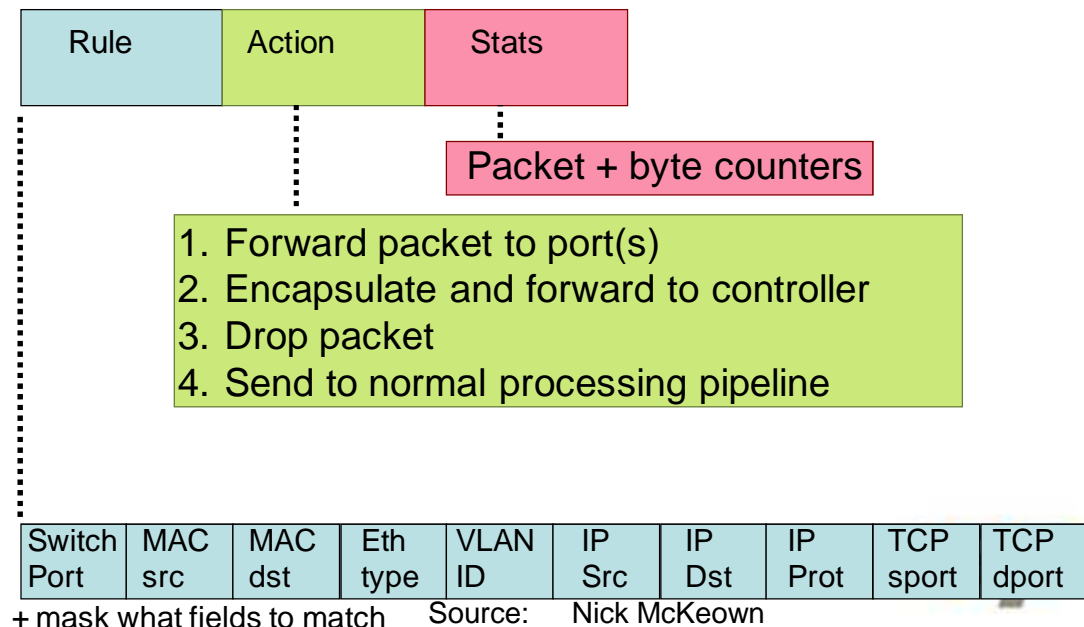
Software-defined networking

- A pragmatic approach to provide a substrate for switch programmability
- Open-source control software
 - Leads to innovation
- Out-source intelligence to commodity PCs
 - Leads to lightweight, inexpensive, commoditized but customizable switches

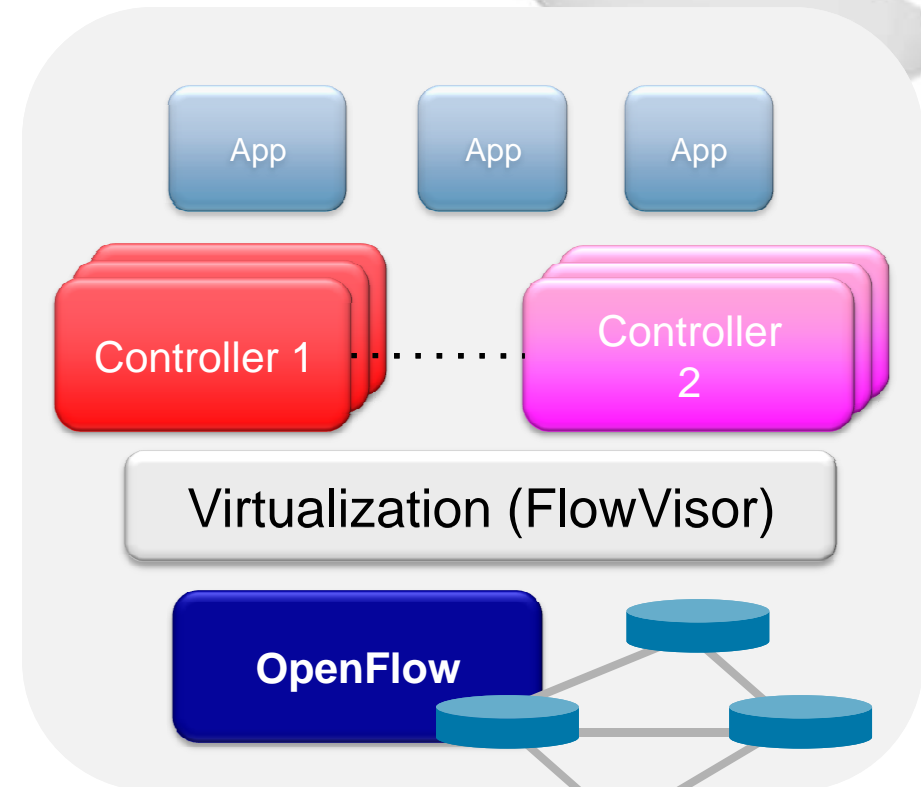
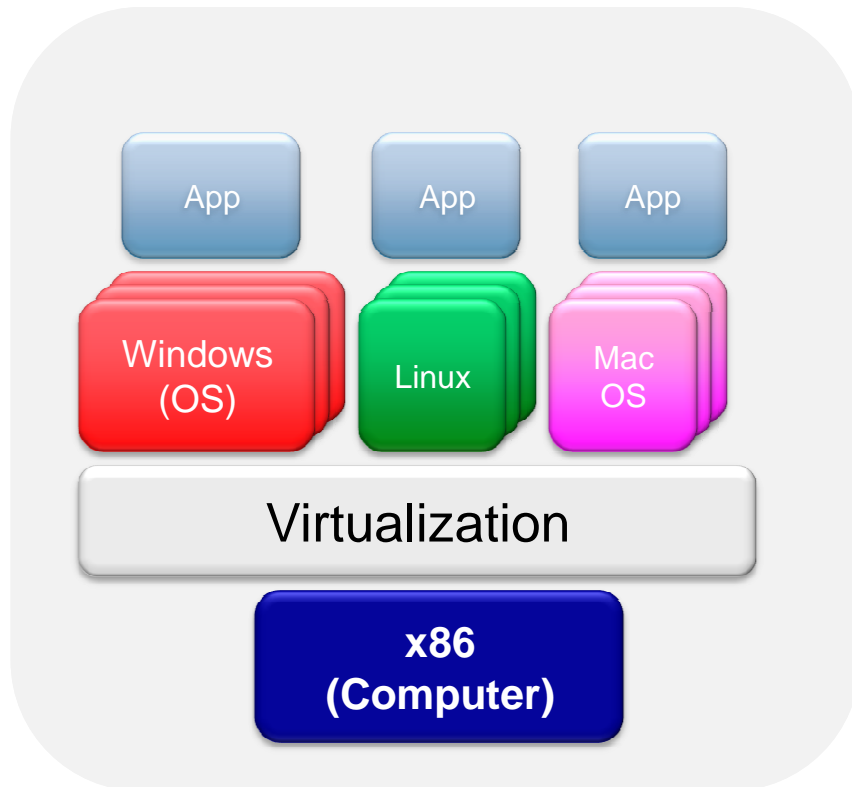
Flow model

- Simple
- Plumbing
- Control
- Rewrite

External open API to flow-table



Following the lessons from PC history



Simple, common, stable, hardware substrate below

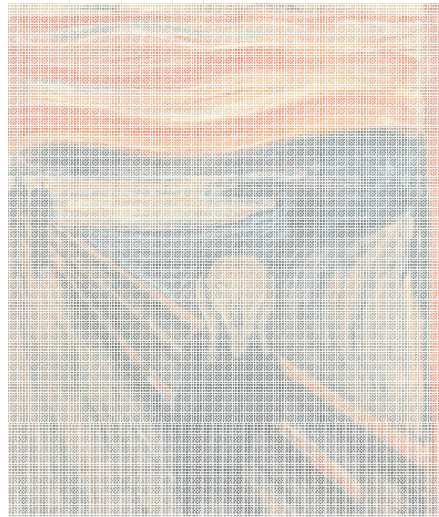
+ Programmability

+ Strong isolation model

+ Competition above

→ Faster innovation, e.g., enable **FI prototyping**

Conclusions



Future Internet

Obrigado!



Perguntas?

