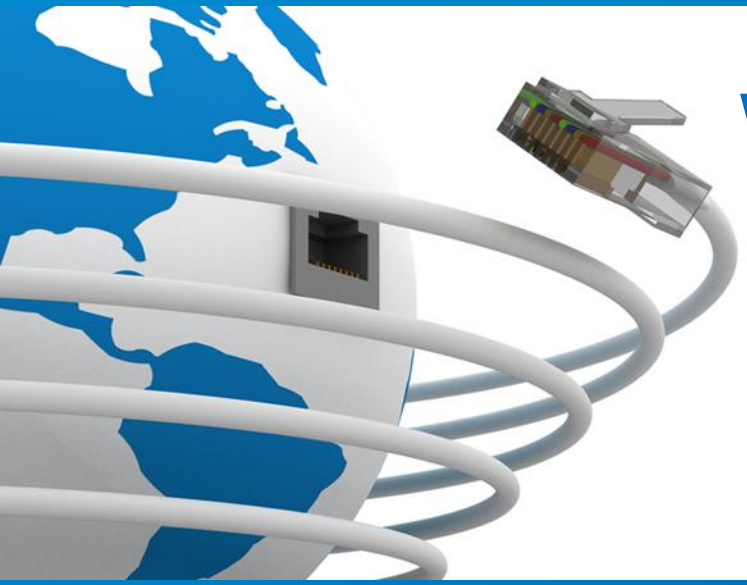


WInternet:

From Net of Things to Internet of Things

Wei Zhao
University of Macau

Outline

Internet = Interconnecting Nets
(of computers)

IOT = Internet of Things

= Interconnecting Nets of Things

Development of Internet: from Net to Internet

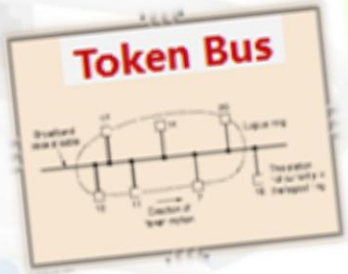
Specialized Electronic networks

1960 1970 1980 1990 2000 2010

Development of Internet: from Net to Internet

Computer Local Area Networks

Principle of networking: Common media and Localized protocols



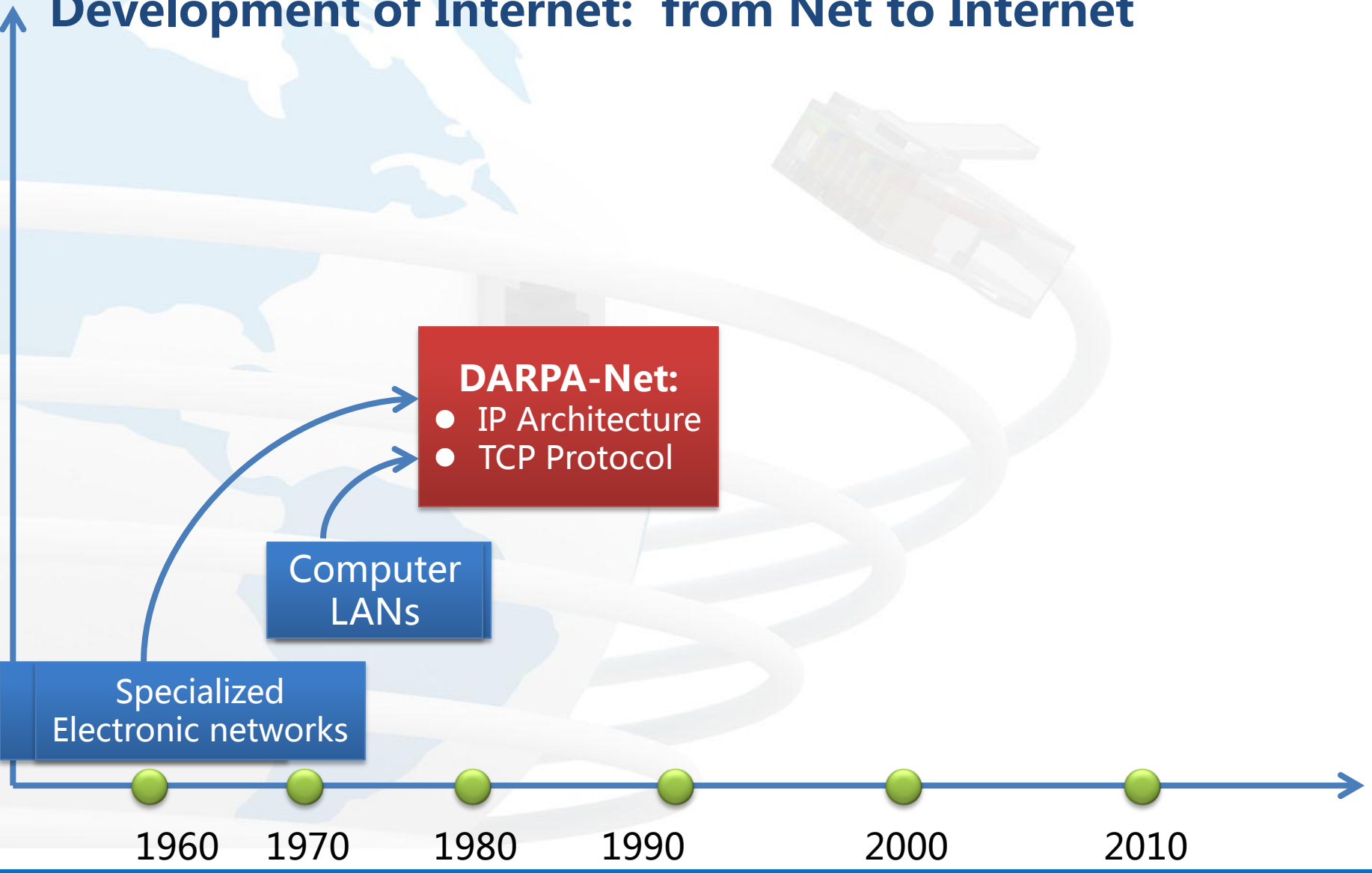
Small scale and not scalable

Computer LANs

Specialized Electronic networks

1960 1970 1980 1990 2000 2010

Development of Internet: from Net to Internet



Development of Internet

Specialized Electronic Networks

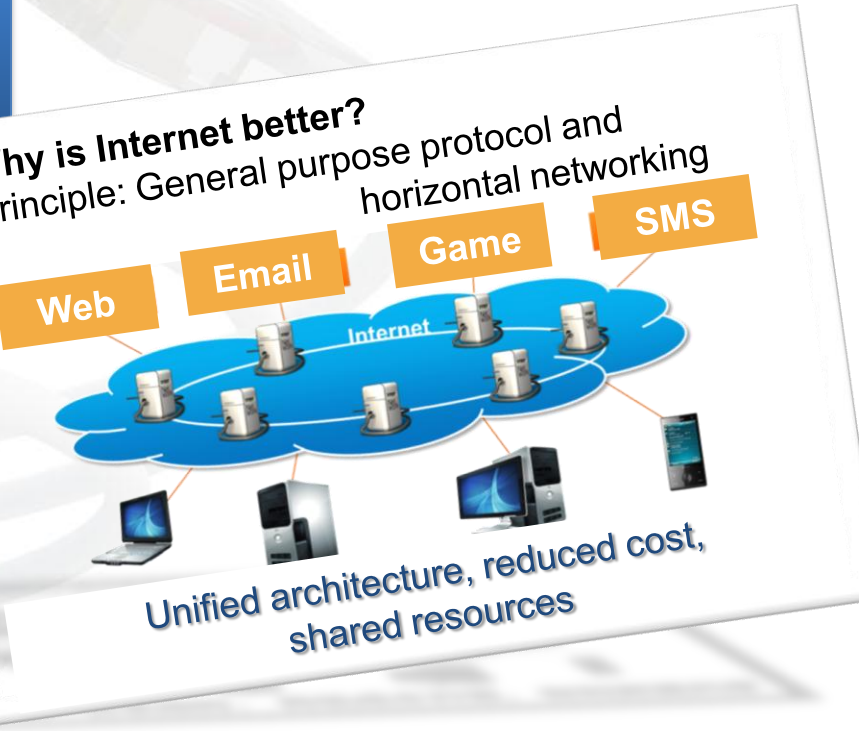
Computer LANs

DARPA-Net:
- IP Architecture
- TCP Protocol

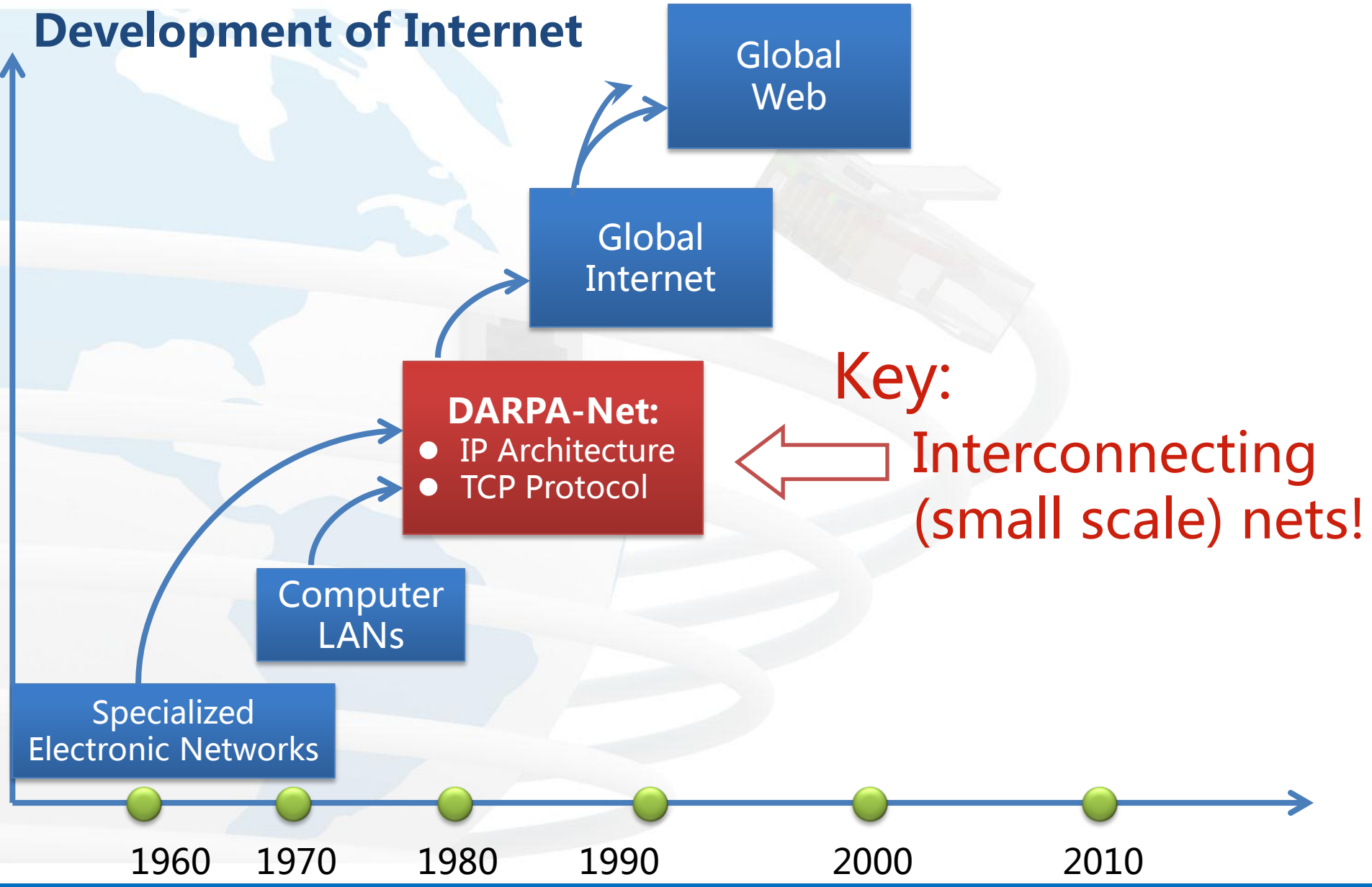
Global Internet

Global Web

Why is Internet better?
Principle: General purpose protocol and horizontal networking



1960 1970 1980 1990 2000 2010


Development of Internet
Global Web
Global Internet
DARPA-Net:
IP Architecture
TCP Protocol
Computer LANs
Specialized Electronic Networks
Key:
Interconnecting (small scale) nets!
1960
1970
1980
1990
2000
2010

Who is the father of the Internet?

Leonard Kleinrock

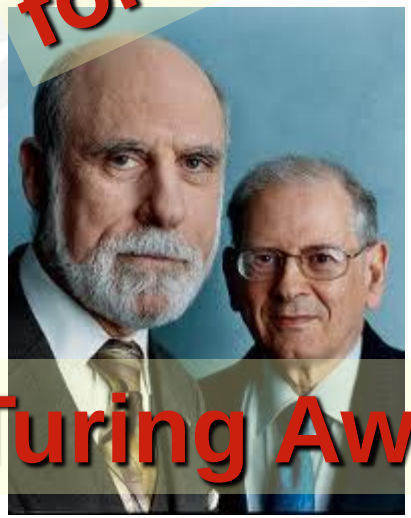
Major Contribution: CSMA/CD

for "net"

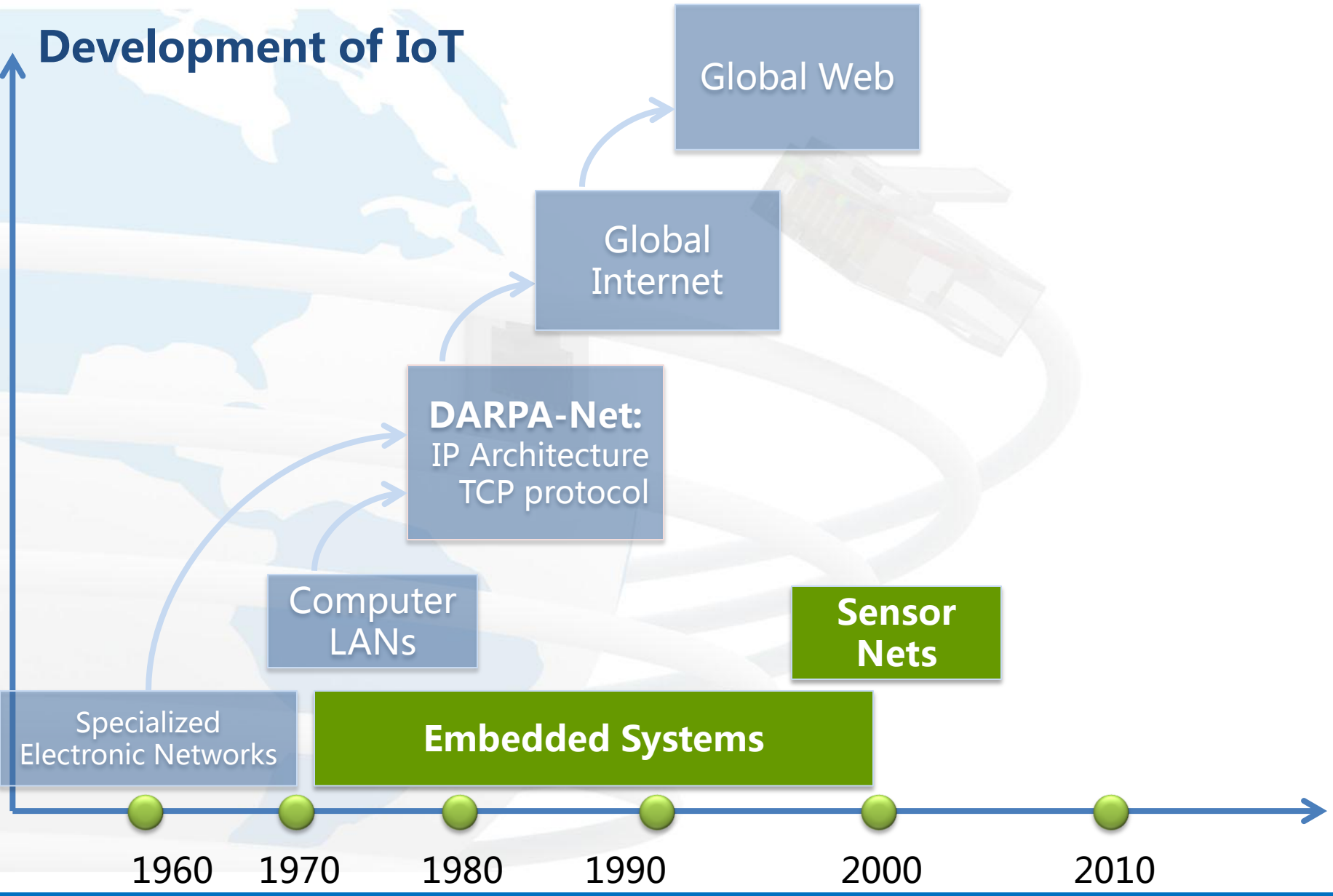
Vinton G. Cerf and Robert E. Kahn

Major Contribution: TCP/IP

for "Internet"



2004 Turing Award!!


Development of IoT
Global Web
Global Internet
DARPA-Net:
IP Architecture
TCP protocol
Computer LANs
Sensor Nets
Specialized Electronic Networks
Embedded Systems
1960
1970
1980
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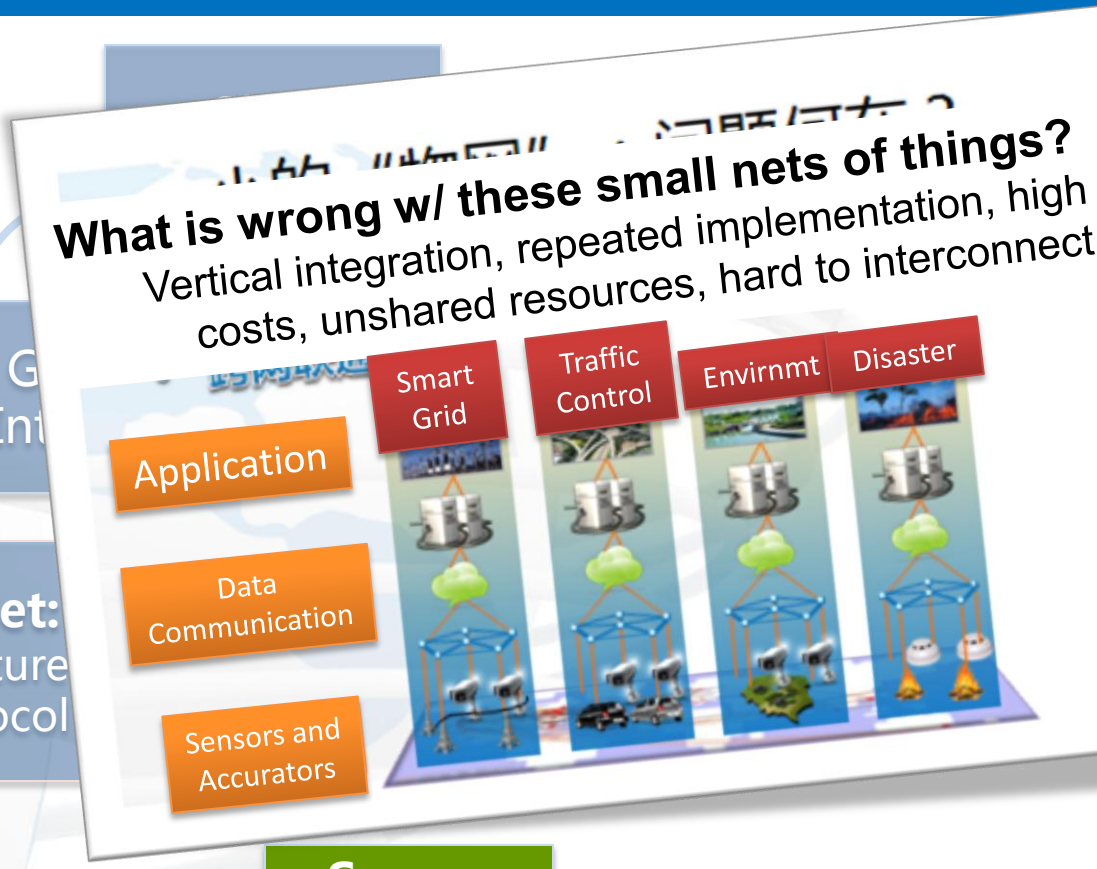
2000
2010

Development of IoT



G
Int

DARPA-Net:
IP Architecture
TCP protocol

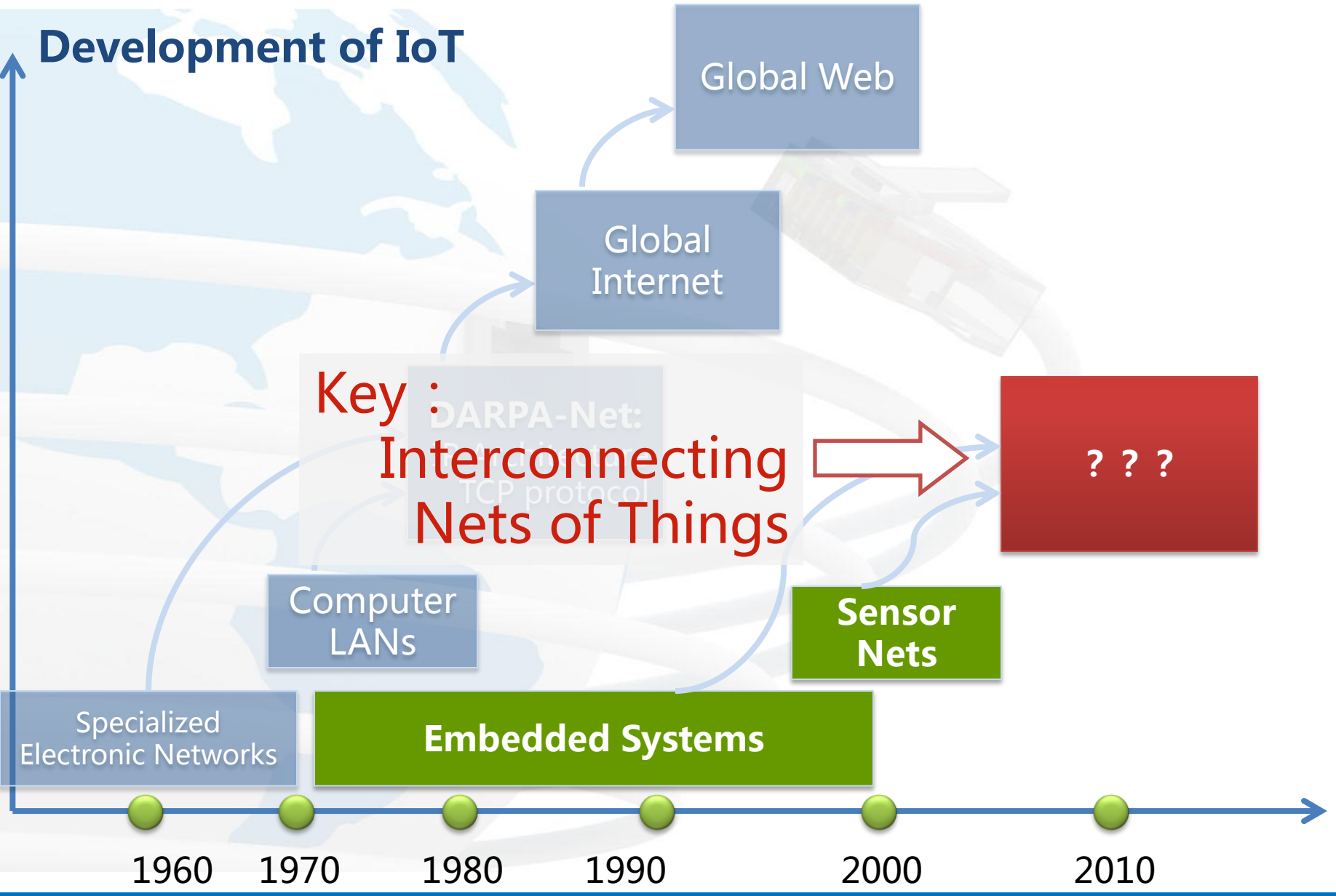
Computer LANs

Sensor Nets

Specialized Electronic Networks

Embedded Systems

1960 1970 1980 1990 2000 2010


Development of IoT
Global Web
Global Internet
Key：
Interconnecting
Nets of Things
? ? ?
Computer LANs
Sensor Nets
Specialized Electronic Networks
Embedded Systems
1960
1970
1980
1990
2000
2010

Forest of Camera Heads

What happens, if not :

2003年 US/Canada Power System Failure

Serbia War by Fax

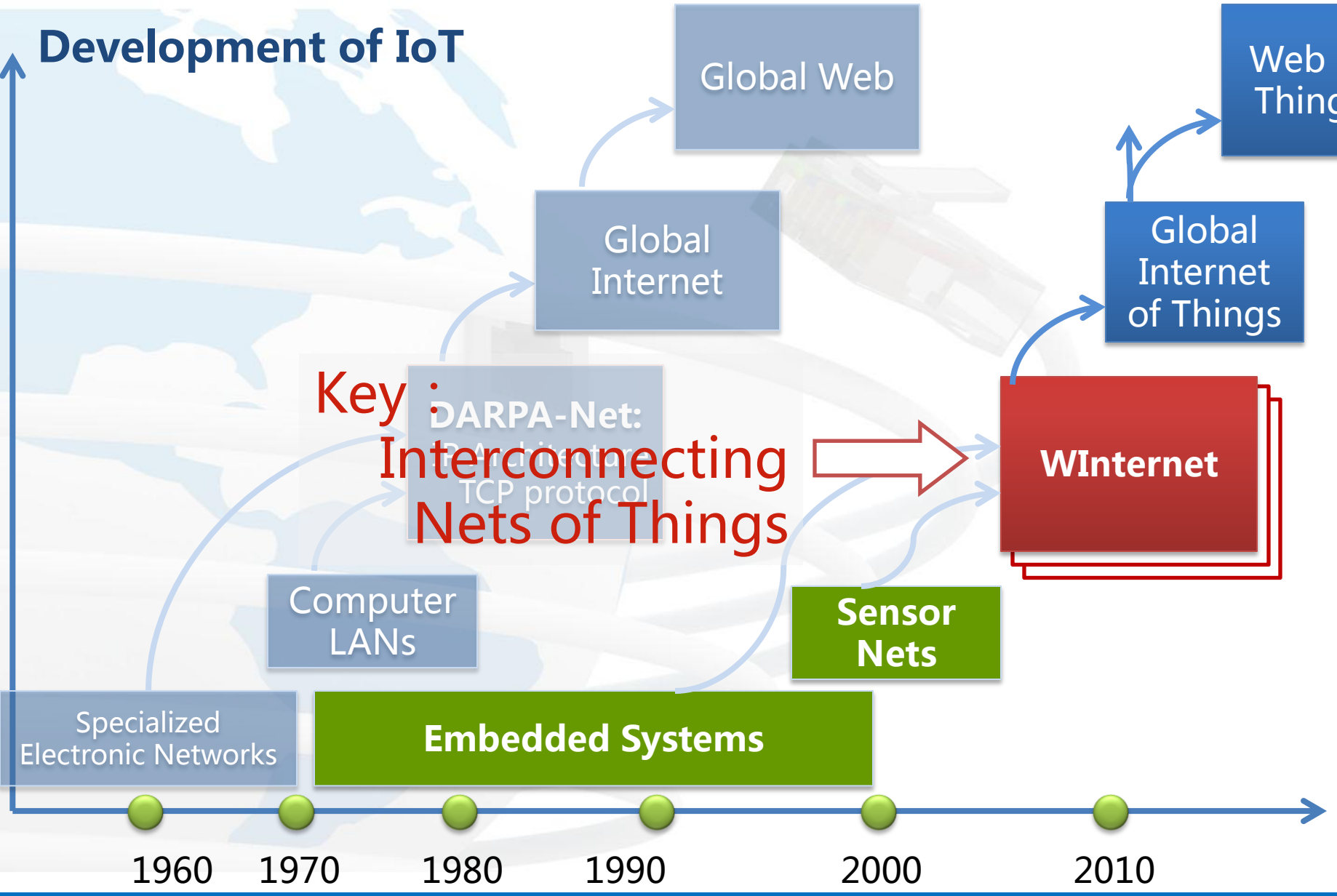
Forest of Camera Heads

A Grand Challenge Problem of IoT:

My daughter on her campus

A father can view activities of his daughter on her college campus:

- with a reasonable cost (say, US$20/month) and
- in real time


Development of IoT
Global Web
Web of Things
Global Internet
Global Internet of Things
Key :
Interconnecting Nets of Things
DARPA-Net:
TCP protocol
WInternet
Computer LANs
Sensor Nets
Specialized Electronic Networks
Embedded Systems
1960
1970
1980
1990
2000
2010

Outline

一、Introduction

二、WInternet 

三、Final Remarks

WInternet

1、System Architecture

2、Networking Issues

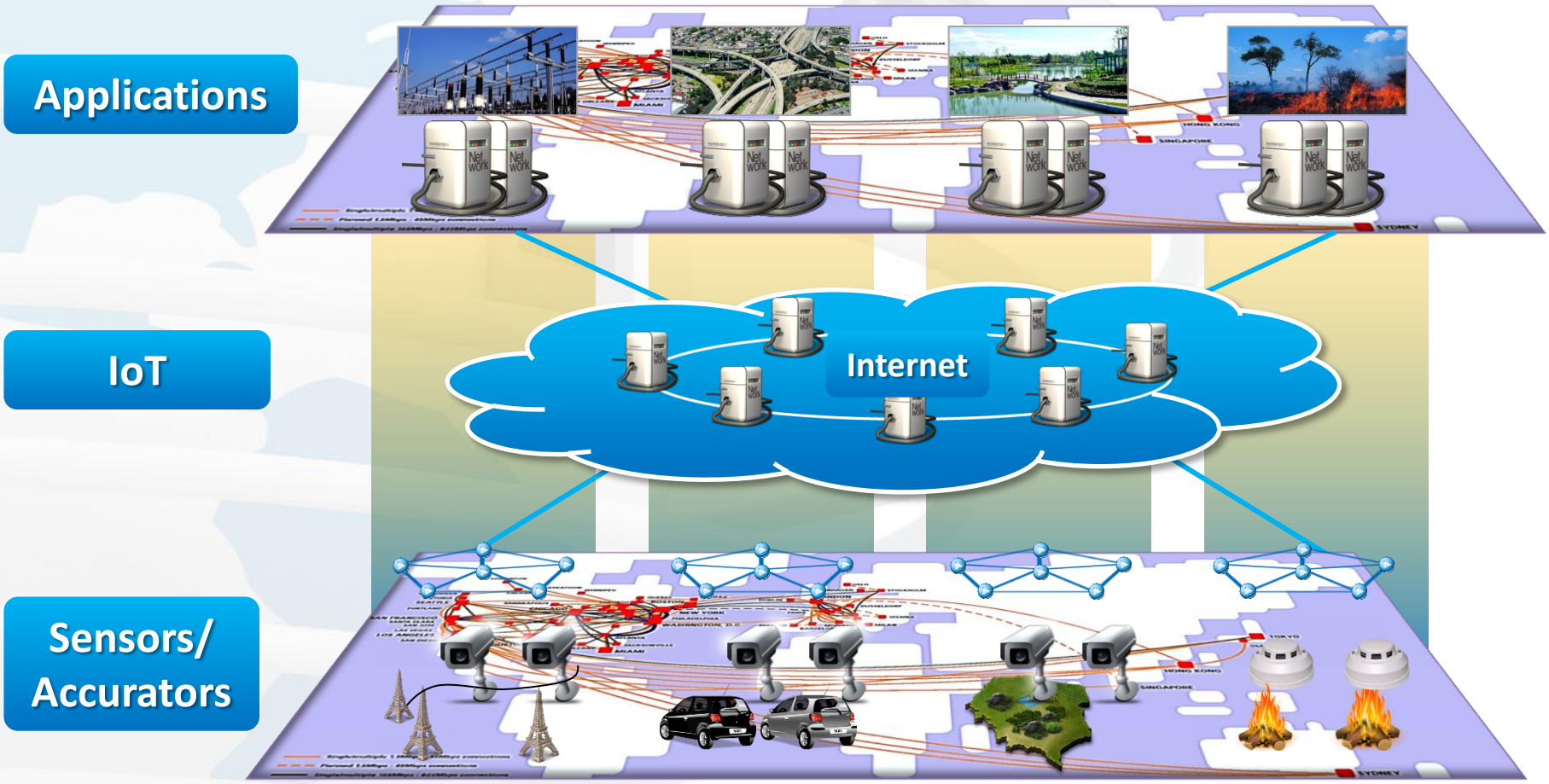
3、Software Issues

4、A Prototype System

Performance Requirements of IoT

Networking	**1. Real Time**
	2. Privacy and Security
Software	**3. Consistency of Cyber and Physical Spaces**
	4. Deterministic of Operations
	5. Computation close to the data sources
Others	**6. Scalability**
	7. Low cost and fast initiations
	8. Marketable and commercially profitable

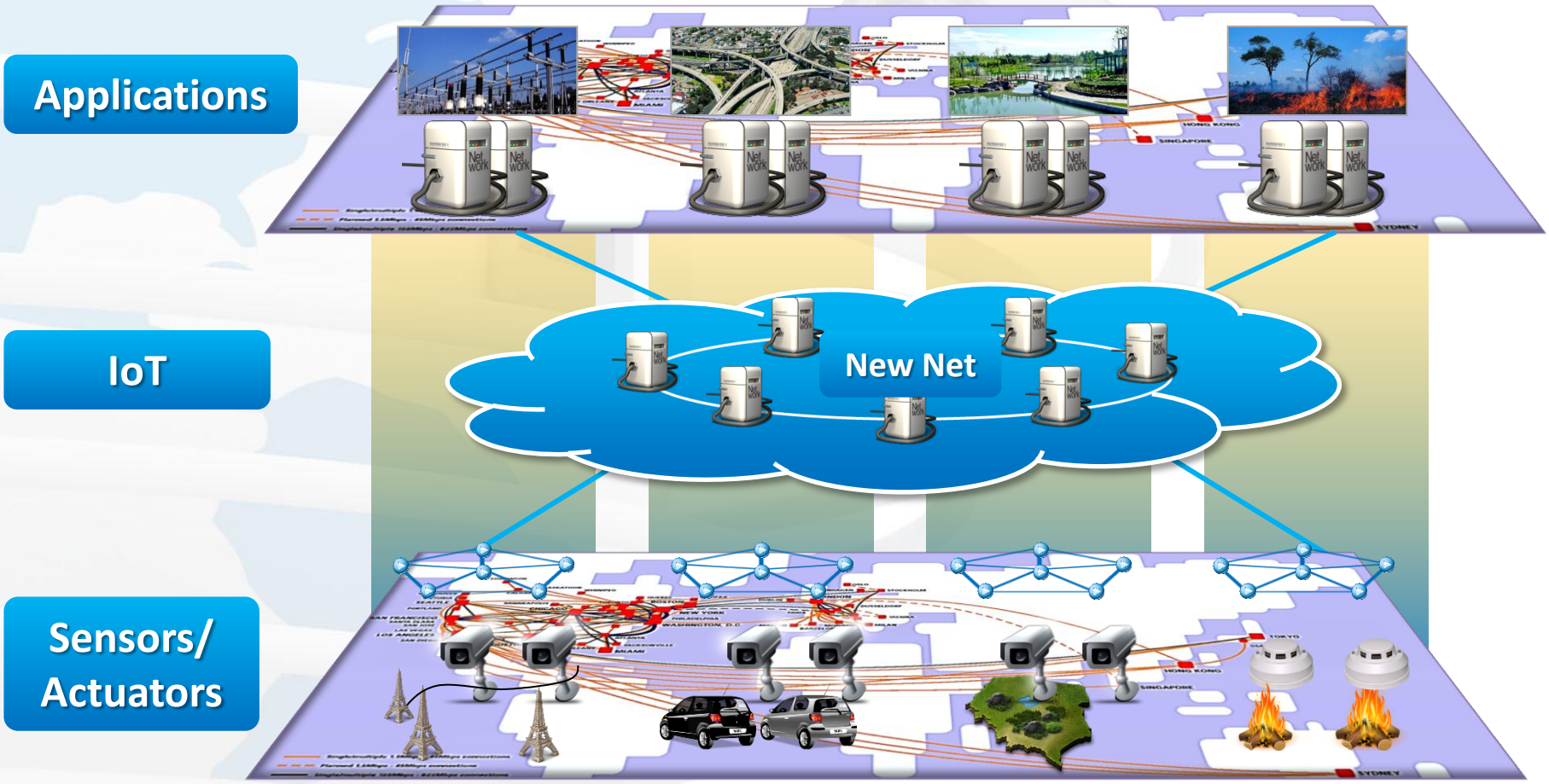
Schema 1: Direct Use of Internet



Evaluation of Schema 1

Requirements of IoT		Schema 1		
Network-ing	1. Real Time	Poor		
	2. Privacy & Security	Poor		
Software	3. Consistency of CPS	Poor		
	4. Deterministic Ops	Poor		
	5. Comp. close to sources	Impossible		
Others	6. Scalability	Good		
	7. Low cost and fast init.	Good		
	8. Marketable &profitable	Poor		
Conclusions		Not Feasible		

Schema 2: To Build a New Network

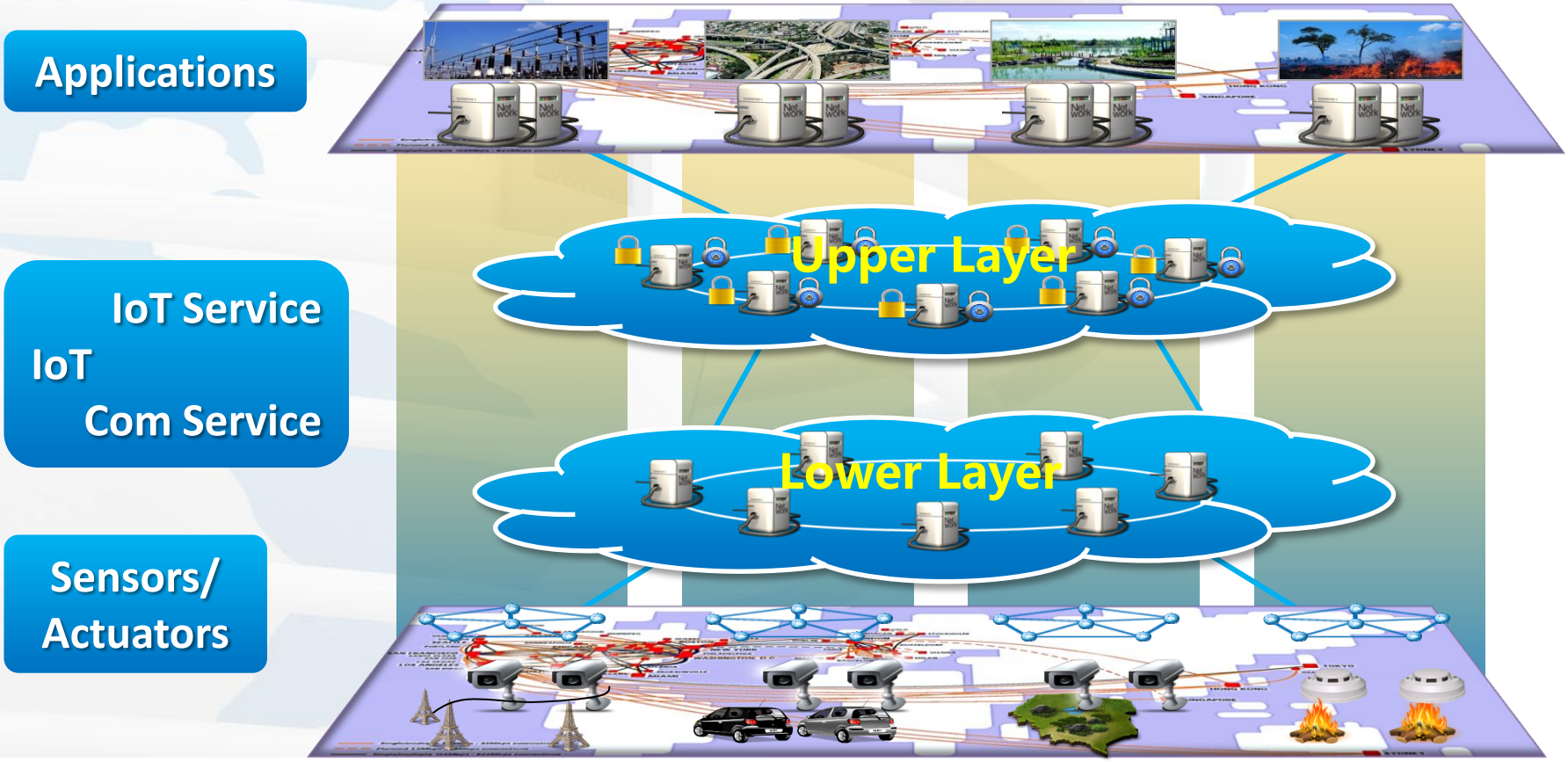


Evaluation of Schemas 1 & 2

Requirements of IoT		Schema 1	Schema 2	
Network-ing	1. Real Time	Poor	Good	
	2. Privacy & Security	Poor	Good	
Software	3. Consistency of CPS	Poor	Good	
	4. Deterministic Ops	Poor	Good	
	5. Comp. close to sources	Impossible	Possible	
Others	6. Scalability	Good	Good	
	7. Low cost and fast init.	Good	Bad	
	8. Marketable &profitable	Poor	Poor	
Conclusions		Not Feasible	High Risk	

Schema 3 : Dual Layer System

Lower Layer : communication media (internet)
Upper Layer : IoT services



Evaluation of Schemas 1, 2, & 3

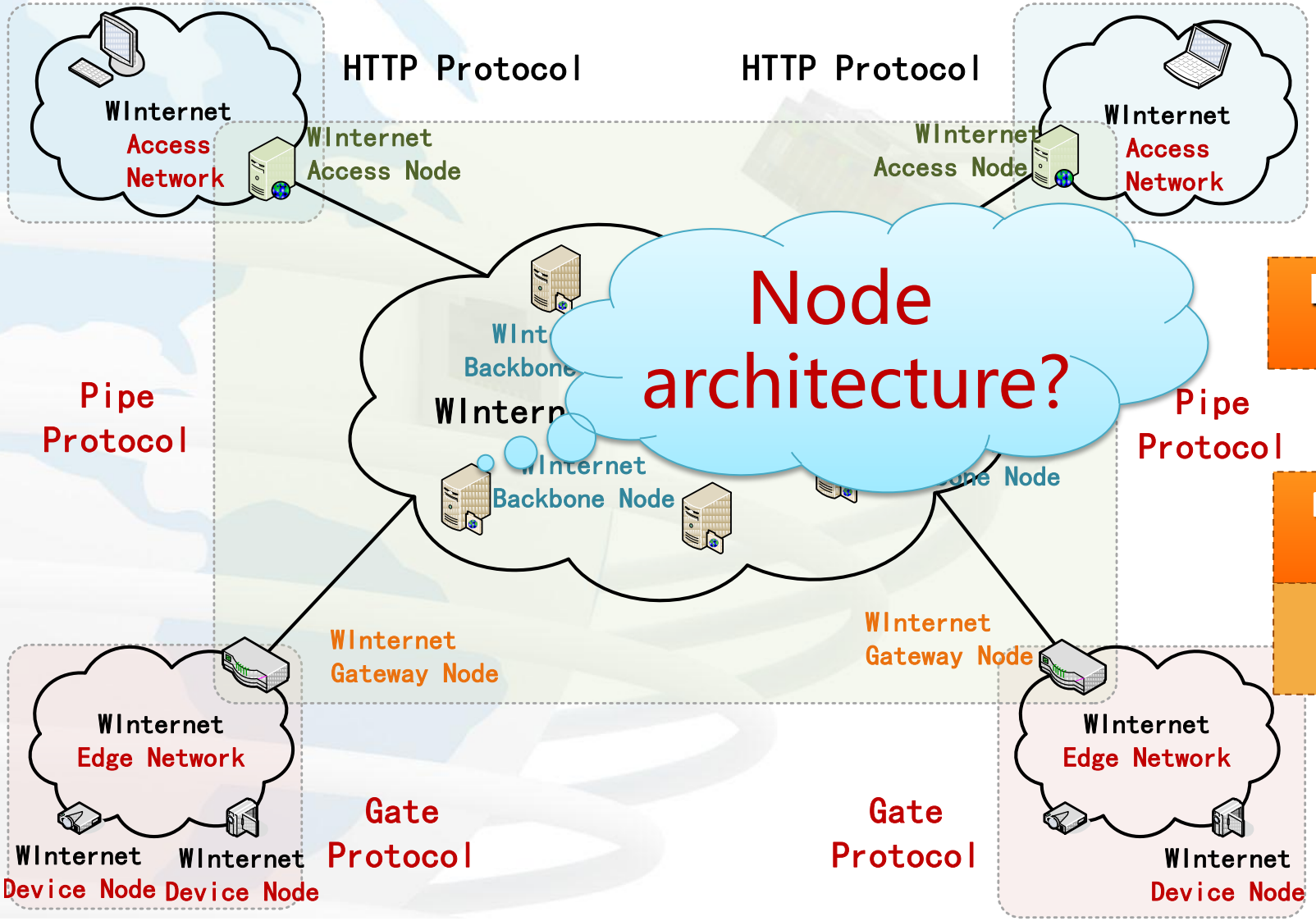
Requirements of IoT		Schema 1	Schema 2	Schema 3
Network-ing	1. Real Time	Poor	Good	Good
	2. Privacy & Security	Poor	Good	Good
Software	3. Consistency of CPS	Poor	Good	Good
	4. Deterministic Ops	Poor	Good	Good
	5. Comp. close to sources	Impossible	Possible	Possible
Others	6. Scalability	Good	Good	Good
	7. Low cost and fast init.	Good	Bad	Good
	8. Marketable &profitable	Poor	Possible	Possible
Conclusions		Not Feasible	High Risk	Possible

WInternet architecture:
A dual layer system

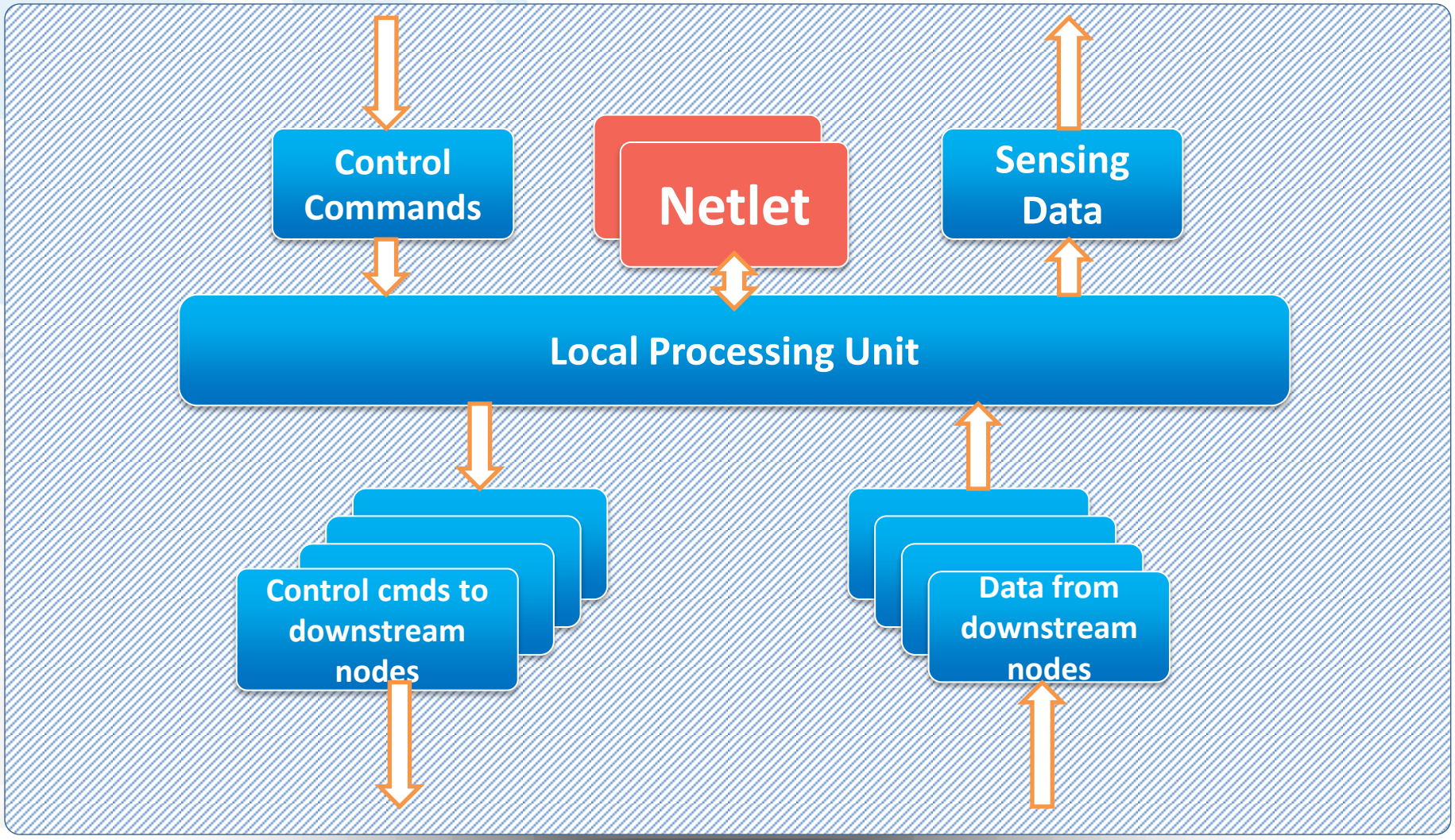
Networking → Pipe Protocol

Software → Netlet Protocol

WInternet Architecture



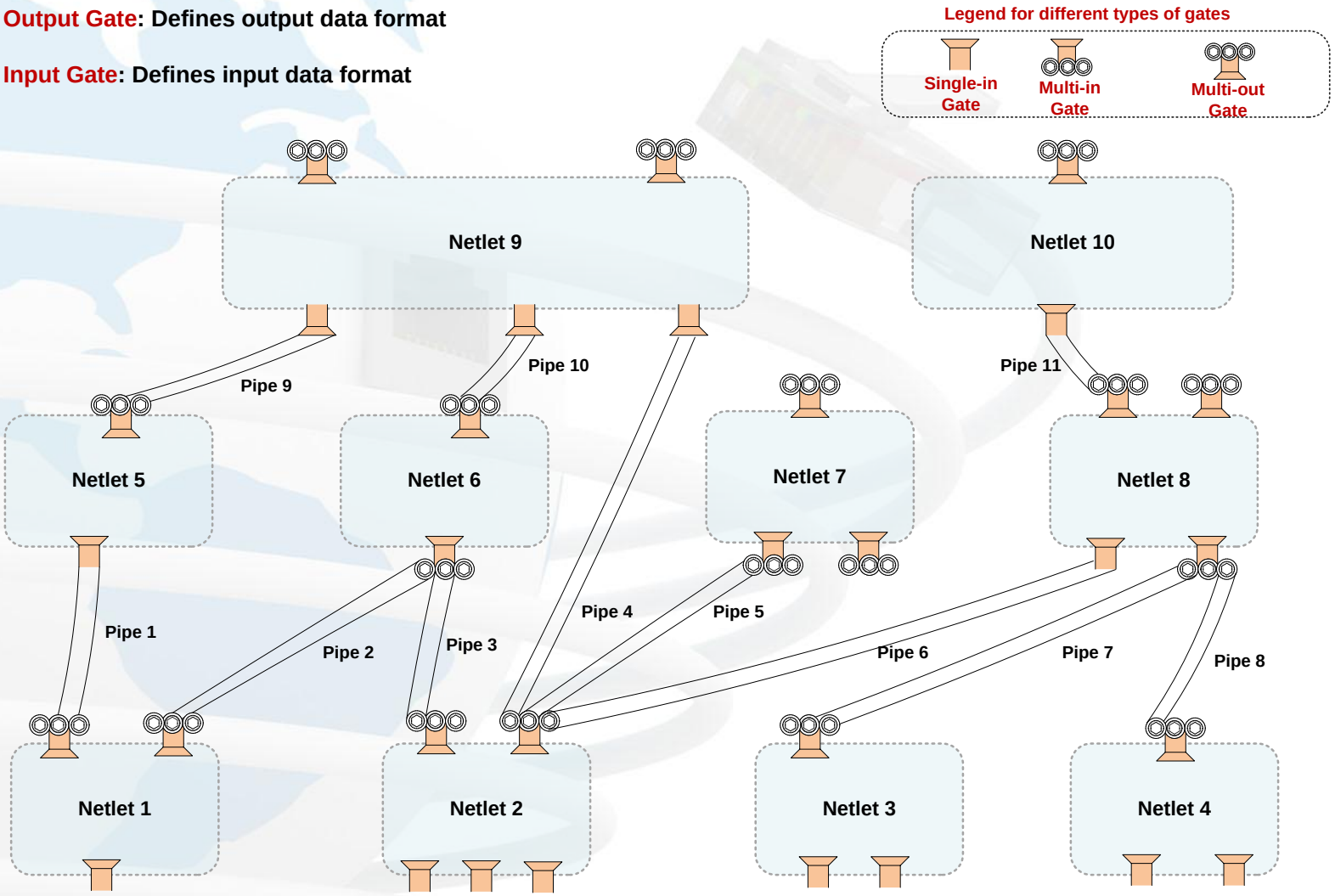
WInternet Node Architecture



WInternet Pipe

Output Gate: Defines output data format

Input Gate: Defines input data format



WInternet

1、System Architecture

2、Networking Issues

3、Software Issues

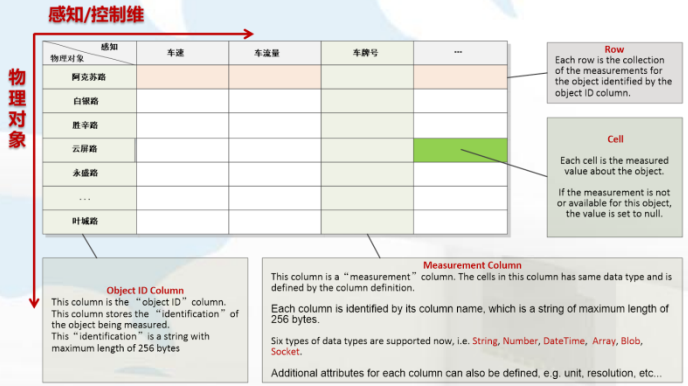
4、A Prototype System

Networking Issues

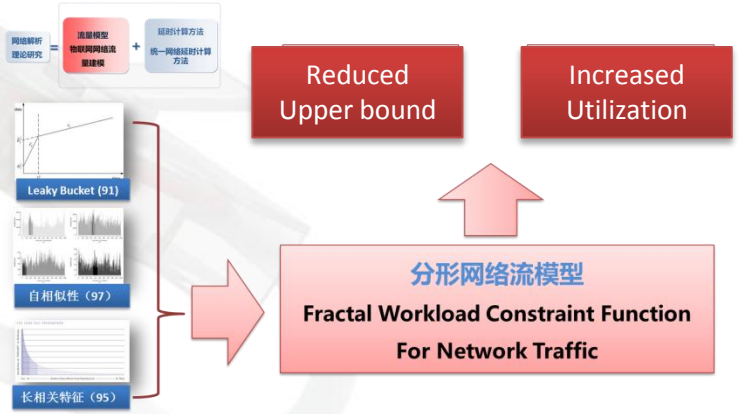
Determine if the delay requirement can be met for the traffic transmitted through the pipes?

1. **Formulize traffic in the pipes**
2. **Establish models for traffic in the pipes**
3. **Derive fast algorithm for determination**
4. **Realize the protocol**

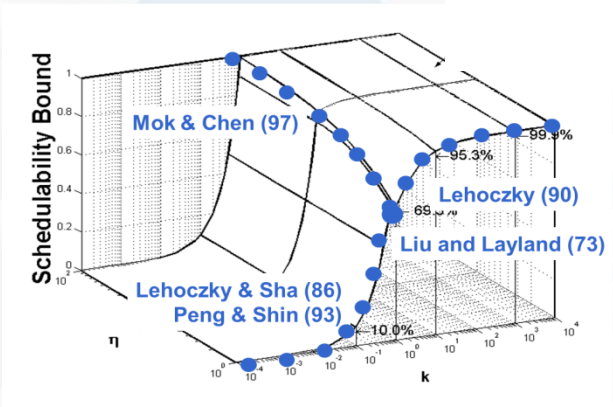
1. Formulization: Data Frame



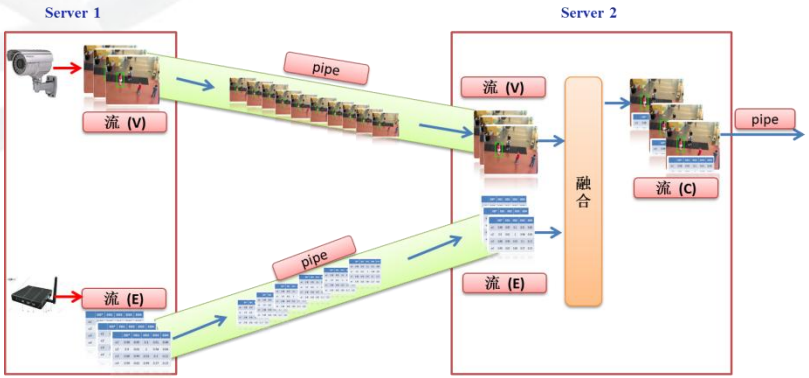
2. Fractal Workload Model



3. Fast Determination Algorithm

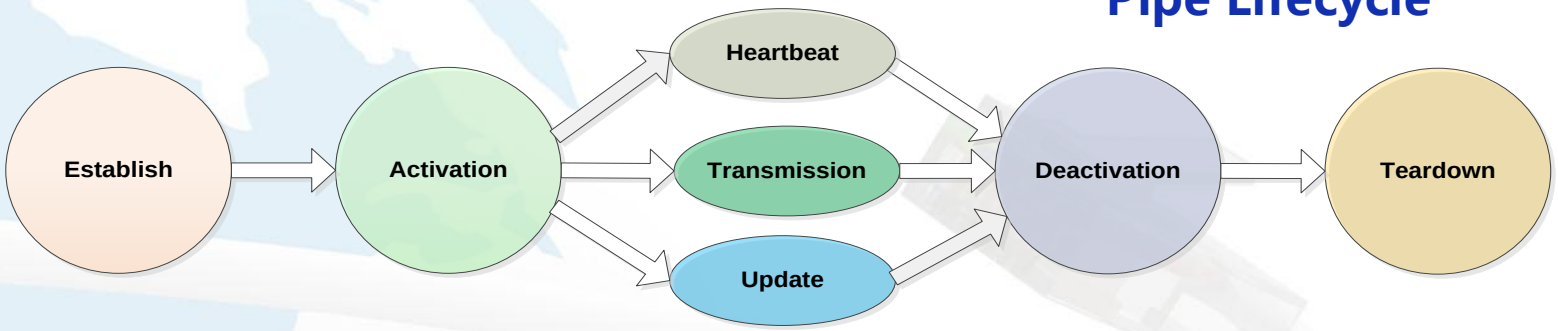


4. The Pipe Protocol

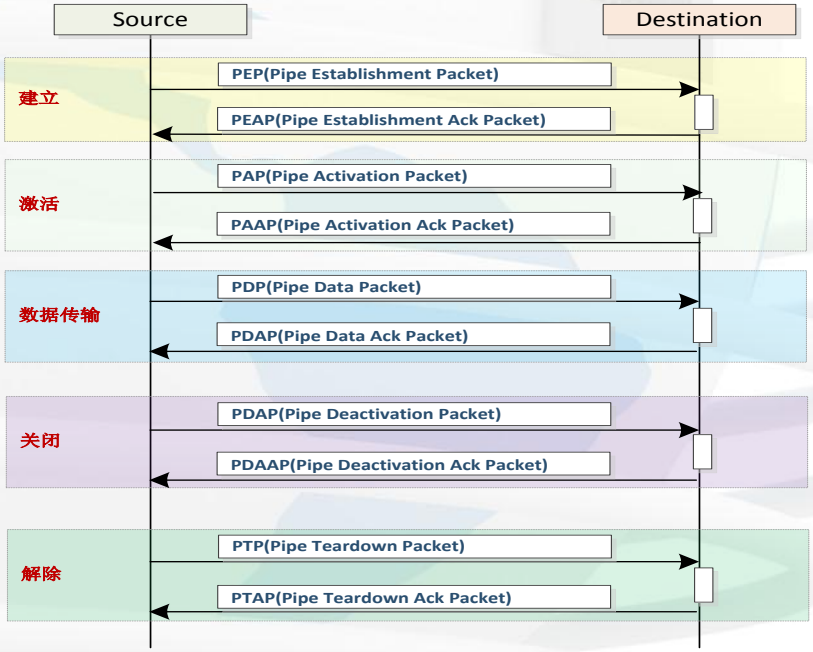


Pipe Protocol: hand shaking

Pipe Lifecycle



Hand Shaking



Packet Format

Packet Format

```
<?xml version="1.0" encoding="UTF-8"?>
<winternet>
  <cmd>establishement</cmd>
  <timestamp>yyyyMMddHHmmss</timestamp>
  <success>true</success>
  <from>
    <NodeName>192.168.1.10:4040</NodeName>
    <!-- Source WInternet Node Name or URL, -->
    <NetletName>VehicleRecogizeNetlet </NetletName >
    <!--WInternet Netlet Name -->
    <GateKey> OutGate8003 </GateKey>
    <!—WInternet source gate id-->
  </from>
  <to>
    <NodeName>192.168.1.210:4040</NodeName>
    <!-- Destination WInternet Node Name or URL, -->
    <NetletName>VehicleTracingNetlet </NetletName >
    <!--WInternet Netlet Name -->
    <GateKey> InGate8003 </GateKey>
    <!—WInternet source gate id-->
  </to>
</winternet>
```

Common Part of a Packet

cmd: could be establishment, activation, deactivation, teardown, heartbeat, update

timestamp: the time the packet sent out

Extended Part of a Packet

This part defines the extend protocol information. For a pipe establishment packet, the following attributes may be included.

from: the source netlet gate information

to: the destination netlet gate information

Ack Packet Format

```
<?xml version="1.0" encoding="UTF-8"?>
<winternet>
  <cmd>establishementAck</cmd>
  <timestamp>yyyyMMddHHmmss</timestamp>
  <success>true</success>
  <pipeId>3453</pipeId><!-- Created pipe id -->
</winternet>
```

Common Part of an Packet

cmd: could be establishmentAck, activationAck, deactivationAck, teardownAck, heartbeatAck, updateAck

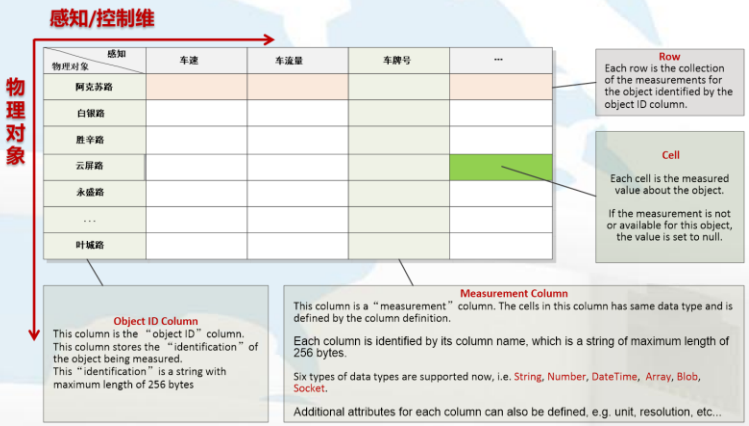
timestamp: the time the packet sent out

success: true/false. If false, message could be returned in extended part.

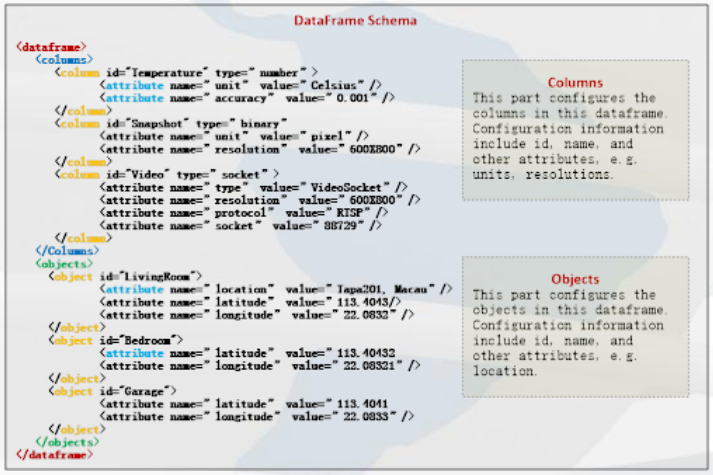
Extended Part of an Ack Packet

Additional information could be put here if needed, e.g. errorMessage, pipeId, etc...

Pipe Protocol: DataFrame



Structured format



XML based definition

Packet Format

```
<?xml version="1.0" encoding="UTF-8"?>
<winternet>
  <cmd>establishement</cmd>
  <timestamp>yyyyMMddHHmmss</timestamp>
  <success>true</success>

  <from>
    <NodeName>192.168.1.10:4040</NodeName>
    <!-- Source WInternet Node Name or URL, -->
    <NetletName>VehicleRecogizeNetlet </NetletName >
    <!--WInternet Netlet Name -->
    <GateKey> OutGate8003 </GateKey>
    <!—WInternet source gate id-->
  </from>
  <to>
    <NodeName>192.168.1.210:4040</NodeName>
    <!-- Destination WInternet Node Name or URL, -->
    <NetletName>VehicleTracingNetlet </NetletName >
    <!--WInternet Netlet Name -->
    <GateKey> InGate8003 </GateKey>
    <!—WInternet source gate id-->
  </to>
</winternet>
```

Common Part of a Packet

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Ack Packet Format

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<winternet>
  <cmd>establishementAck</cmd>
  <timestamp>yyyyMMddHHmmss</timestamp>
  <success>true</success>

  <pipeId>3453</pipeId><!-- Created pipe id -->
</winternet>
```

Common Part of an Packet

cmd: could be establishmentAck, activationAck, deactivationAck, teardownAck, heartbeatAck, updateAck

timestamp: the time the packet sent out
success: true/false. If false, message could be returned in extended part.

Extended Part of an Ack Packet

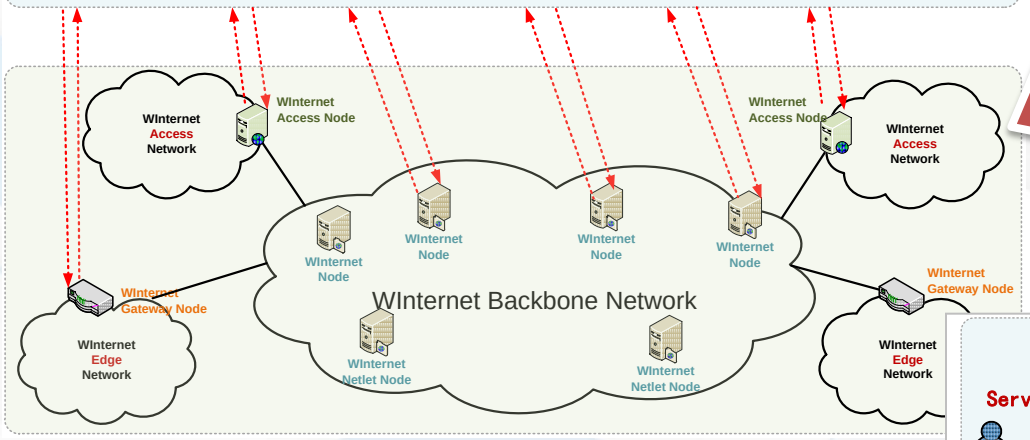
Additional information could be put here if needed, e.g. errorMessage, pipeId, etc...

HTTP compatible

Pipe Protocol: Naming System

WInternet Naming Table

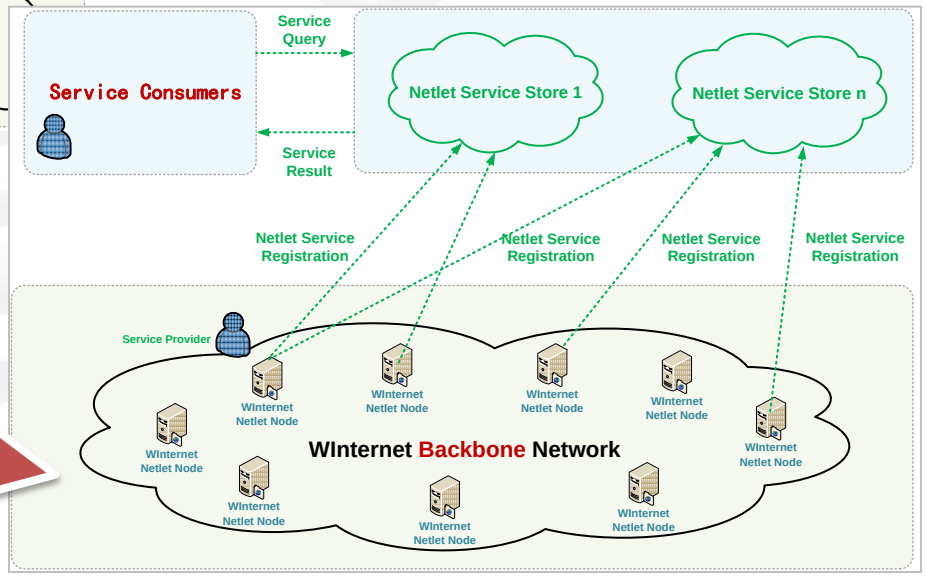
Name	Address	Owner Signature	Type	...
temperature.ict.beijing.china	202.102.112.32:4040/ict_temp	DDEAEFDJKDDCXFD97D0323	NETLET	
temp.iotlab.encu	114.21.2.3:5050/encu_temp	FFEEDD9333DFD3GJKLKJKJK	NETLET	
server.encu.iotlab	114.21.2.3:5050	FFEEDD9333DFD3GJKLKJKJK	NetletNode	



"Netlet Listing"

1. Naming Node and Netlet
2. Roaming Support
3. A P2P non-centralized approach

"Netlet Service Listing"
Support Service Roaming



WInternet

1、System Architecture

2、Networking Issues

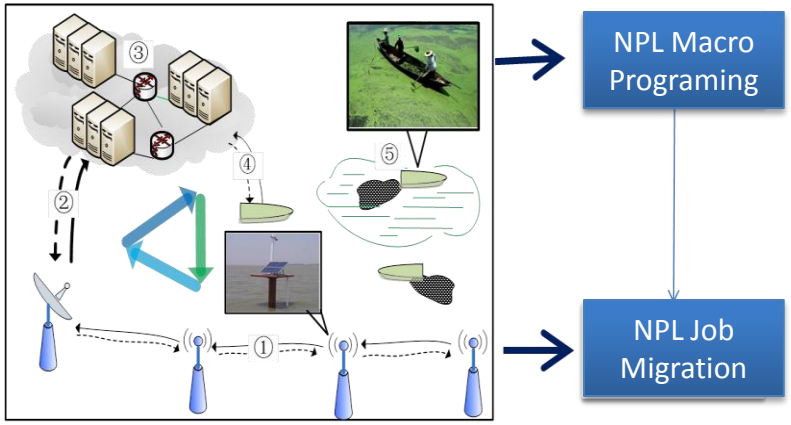
3、Software Issues

4、Prototype Systems

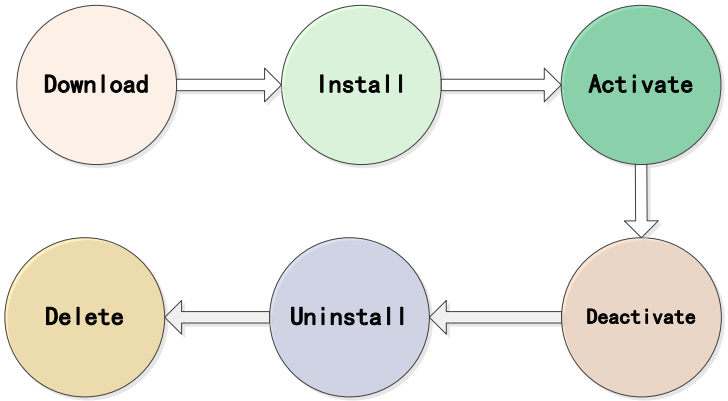
Software Issues

- **Netlet management**
  a. Programming methodology
  b. Distribution system
- **Cyber-physical consistency(CPC) assurance**
  a. Design-time verification method
  b. Run-time guarantee mechanism

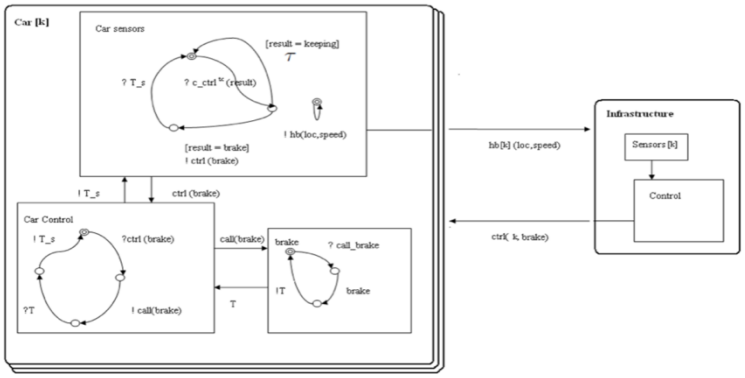
1. Netlet Programming



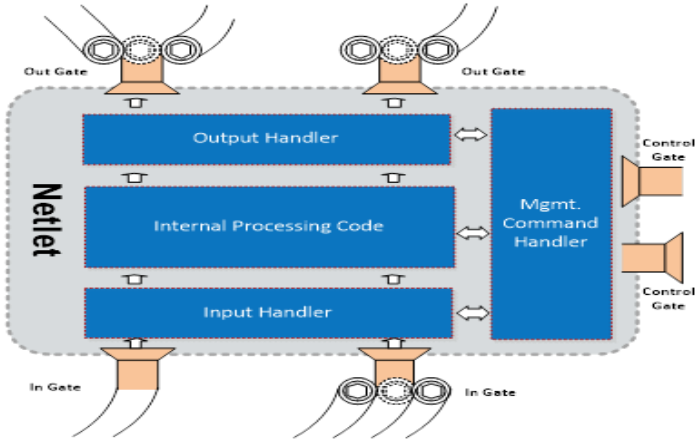
2. Netlet Distribution & Installation



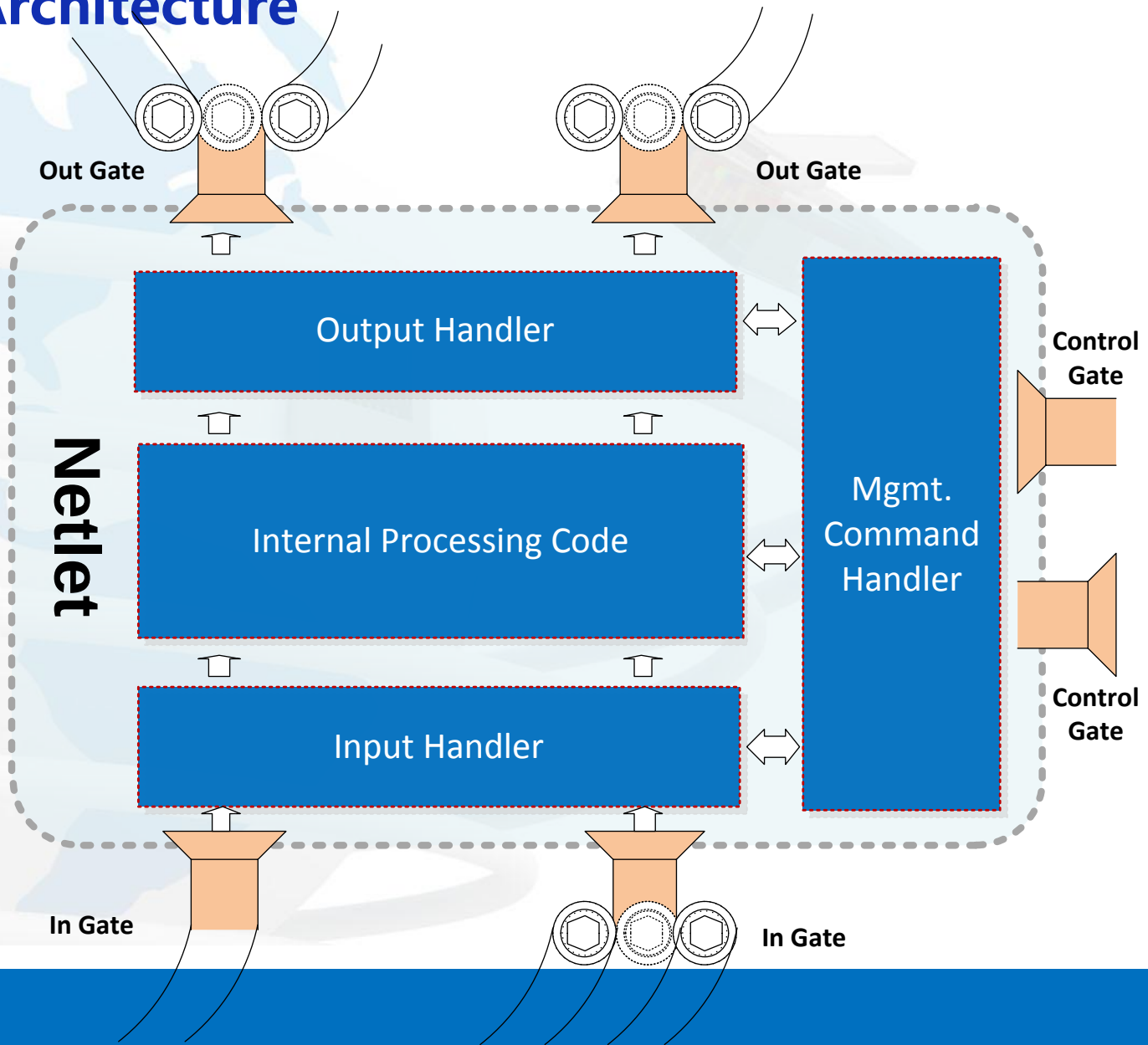
3. STeC: Verification of CPC



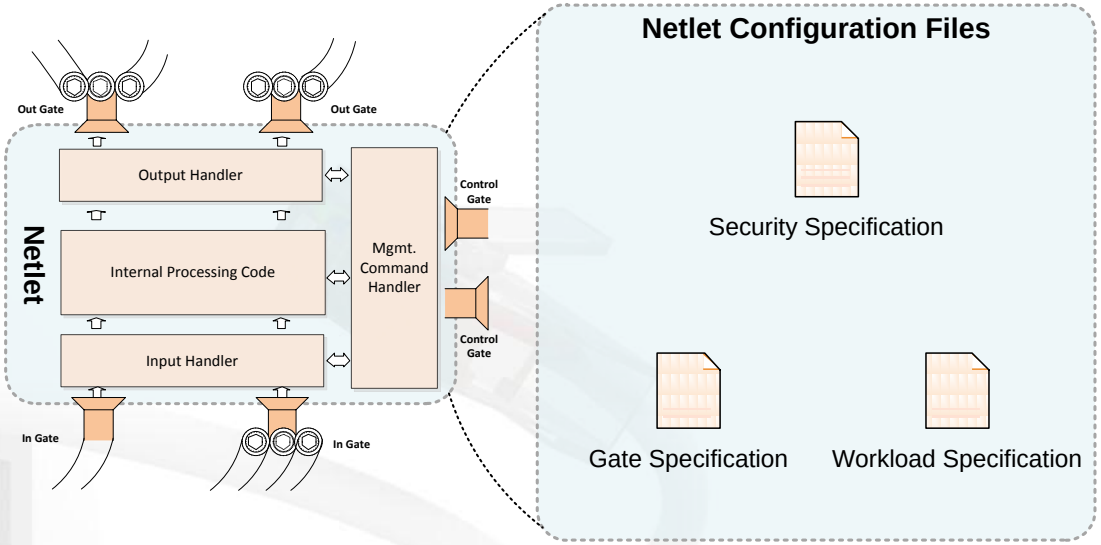
4. Guarantee Mechanism for CPC



Netlet Architecture



Netlet Configurations



Gate Specification

Gate Specification

```
<gates>

   <in>
      <gate id=" 1" name=" ..." maxPipe=" 1" minPipe=" 0">
          <dataFrameSchema=" url to dataframe schema" >
      </gate>
      ...
   </in>
   <out>
      <gate id=" 3" name=" .." maxPipe=" 1" minPipe=" 0">
          <dataFrameSchema=" url to dataframe schema" >
      </gate>
      ...
   </out>

   <management>
      <gate id=" mgtgate" name=" ..." passowrd=" " >
      </gate>
   </management>
</gates>
```

In Gate Config
This part configures the gates of this netlet, including its id, name, max number of allowed connection(pipe), minimum number of allowed connections (pipe), and the dataframe format supported by this gate.

Out Gate Config
This part configures the outpt gates of this netlet, including its id, name, max number of allowed connection(pipe), minimum number of allowed connections (pipe), and the dataframe format supported by this gate.

Management Gate Config
This part configures the management gate information.

Real-time Properties

Workload Specification

```
<realtime>

   <workload>
      <resource type=" cpu" >
          <period=" 10 second" >
          <execution=" 1 second" >
      </resource>
      ...
   </workload>

   <qos>
      <delay max=" 30 second" type=" hard|soft|null" >
   </qos>

</realtime>
```

Workload Config
This part configures the workload information for this netlet, e.g. its CPU resource requirments.

Qos Config
This part configures the qos requirements, e.g. delay requirements type, hard: guarantee resource at installation time, soft: guarantee at activation time, or null, best effort guarantee.

Security Properties

Security Specification

```
<security>
   <signature>
      ...
   </signature>

   <acl>
      <password>
          <adminUser=" admin" password=" 123456" >
          ...
      </password>
      <certificate>
          <adminUser=" admin" publicKey=" xxx" >
          ...
      </certificate>
   </acl>

</security>
```

Signature Config
This part stores the signed text by authorized netlet CA. WInternet engine or netlet service consumers can use this signature to authenticate it.

ACL Config
This part configures which user can control this netlet. User information can be specified by username/password, or by user certificates(accepted public key).

WInternet

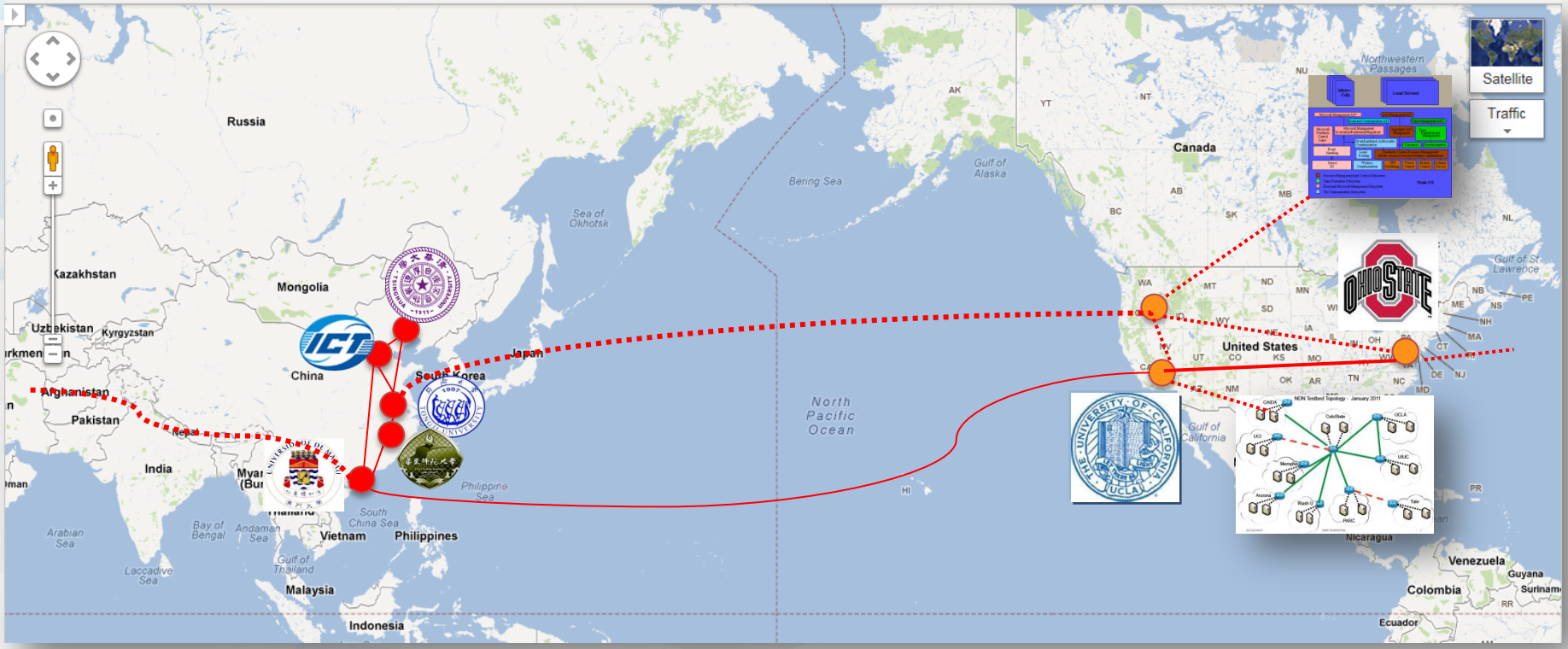
1、System Architecture

2、Networking Issues

3、Software Issues

4、Prototype Systems

WInternet Networking Demonstration



WInternet-based Applications

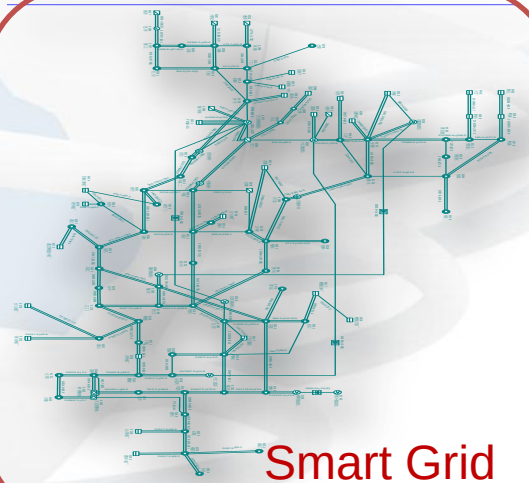
Environmental Monitoring

Winternet Ready Devices




PMU

Vehicle Tracking



Smart Grid

Intelligent Traffic Control

Demo of a Vehicle Tracking System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Outline

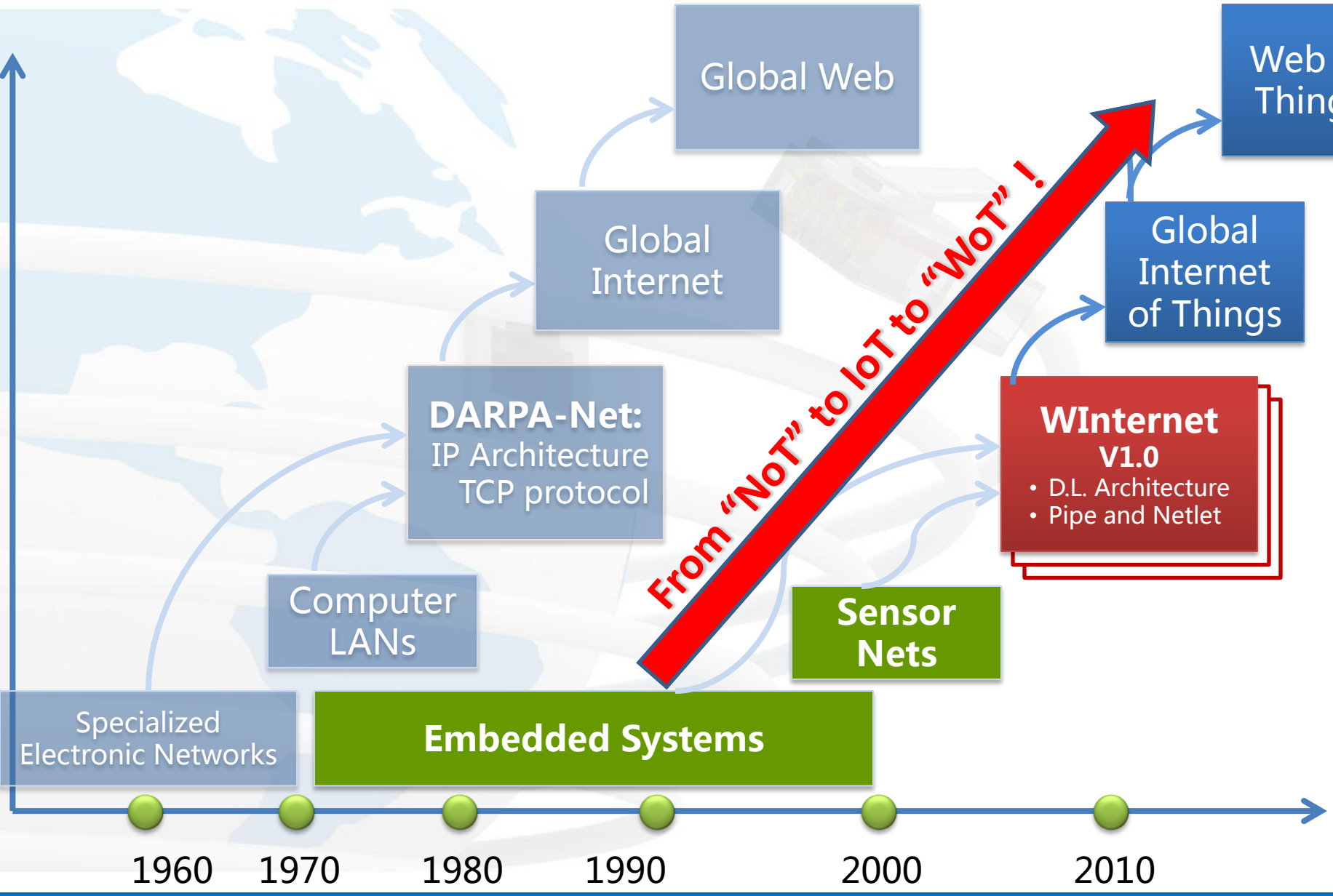
1、Introduction

2、WInternet

3、Final Remarks

Summary

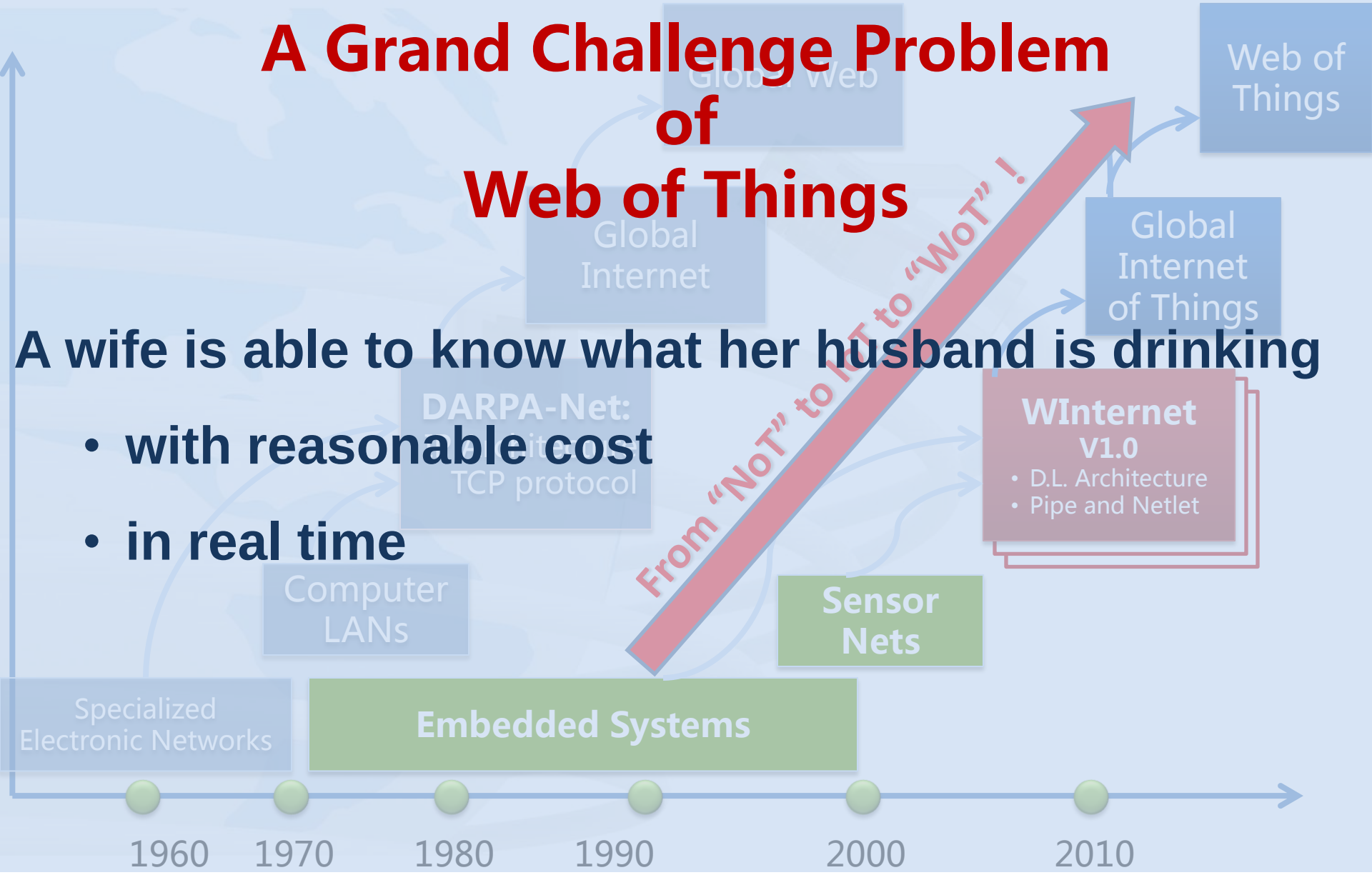
1. IoT must inter-connect (many) "Nets of Things"
2. Based on a dual layer architecture, WInternet effectively realizes an IoT (first globally?)
3. Key technologies in WInternet
   - Pipe communication protocol set
   - Netlet computation protocol set


Global Web
Web of Things
Global Internet
Global Internet of Things
DARPA-Net:
IP Architecture
TCP protocol
WInternet
V1.0
• D.L. Architecture
• Pipe and Netlet
From "NoT" to IoT to "WoT" !
Computer LANs
Sensor Nets
Specialized Electronic Networks
Embedded Systems
1960
1970
1980
1990
2000
2010

Open Issues

1. Define, realize, and promote general protocols
2. Explore more effective lower layer communication system
3. Establish legal framework for physical information
4. Develop address and search methods for physical information

A Grand Challenge Problem of Web of Things



A wife is able to know what her husband is drinking

- **with reasonable cost**
- **in real time**

Thank you!