Evolution Vs Revolution

- After the first NIST workshop, five AMI system vendors – Aclara, Elster, Itron, L+G, Sensus – sent a letter to Dr. George Arnold

- The vendors support the NIST process but expressed concerns related to the direction of the workshop and statements made by key participants

- The vendors felt that the focus should be on … setting forth a minimal set of standards to ensure interoperability between systems …

- …. And that the focus should not be …
    - On developing a “new architecture” for the Smart Grid, or,
    - Immediately promoting opportunities for new, untried, technologies, and,
    - That it should not effectively devalue solutions that are providing value to utilities

In essence, the message was … let’s have evolution, not revolution

Evolution Vs Revolution

AMI System Vendors – Key Principles For Standards Selection

- Any standards should be agnostic with respect to physical layer implementation
- End to end implementation of IP should not be mandated
- Adaptors, translators and other interface devices should be considered as appropriate means for achieving interoperability
- Selected standards should be openly published and ratified by an SDO, industry alliance or a well recognized users group

Any controversy related to these principles seems to revolve around the <u>issue of end to end IP</u>

Evolution Vs Revolution

***Appropriate* Use of the Internet Protocol in Smart Grid Systems**

Most, If Not All, present AMI Vendors Use the **I**nternet **P**rotocol in Their Networks

Discussion

- Should IP be used as the native communication for all levels of communication?
  Backend?
  Collectors?
  Meters?
  Every Endpoint?

- What is The Internet Protocol?
  "IP" (OSI Layer 3) is a Message Format & Addressing Scheme.
  However, the IETF Shows 2734 Different RFCs.
  Which of These Do We Adopt?

- What is the Cost of Implementing IP in its Broad Sense?

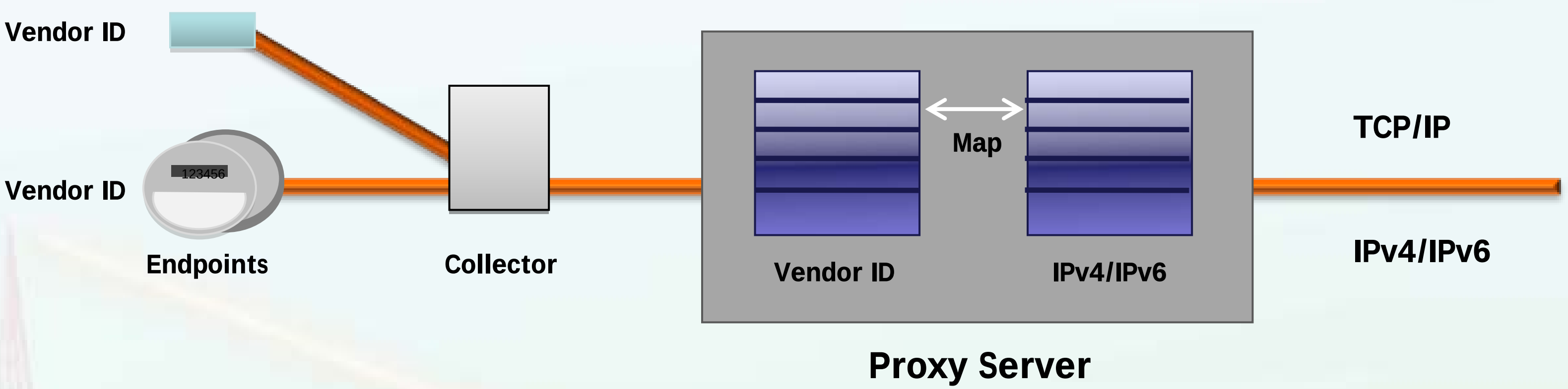
- Conservatism Would Suggest an Evolutionary Path

IP Addressability – First Step

Address Mapping (similar in concept to ARP, Address Resolution Protocol):

PRO - Proxy Server – No Impact on Network or Latency; Legacy Systems Can Comply

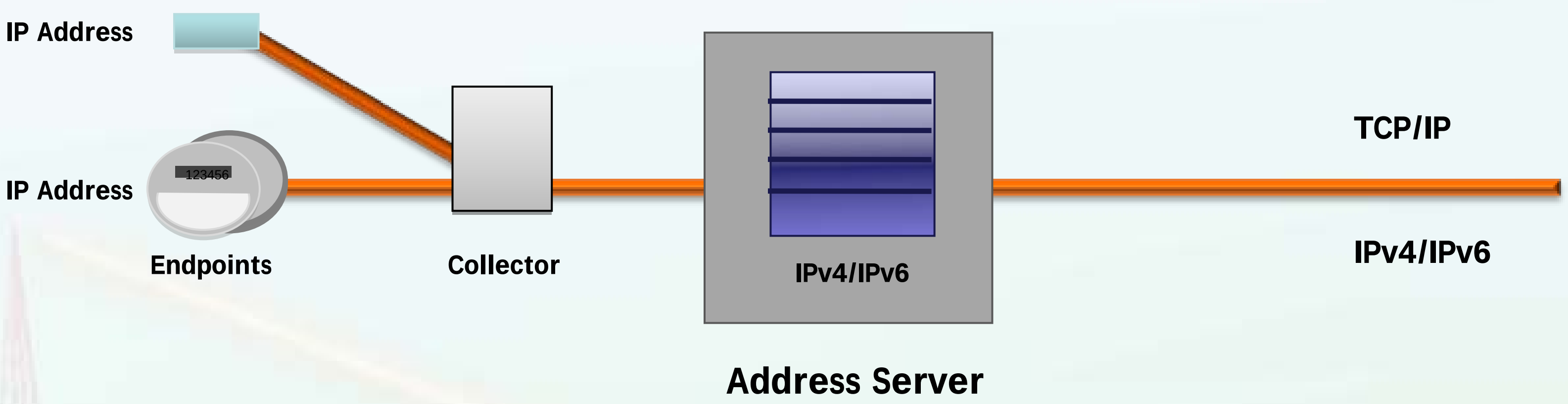
CON – Requires Maintenance; Mitigated by Utility Control & Common Upgrade Practice



IP Addressability – Second Step

Assigned IP Addresses – Small Increase in Network Traffic, Small Modification to Existing Protocol

- **PRO** – Same address end-to-end
- **CON** – Address space requirements and allocation, changes to Protocols

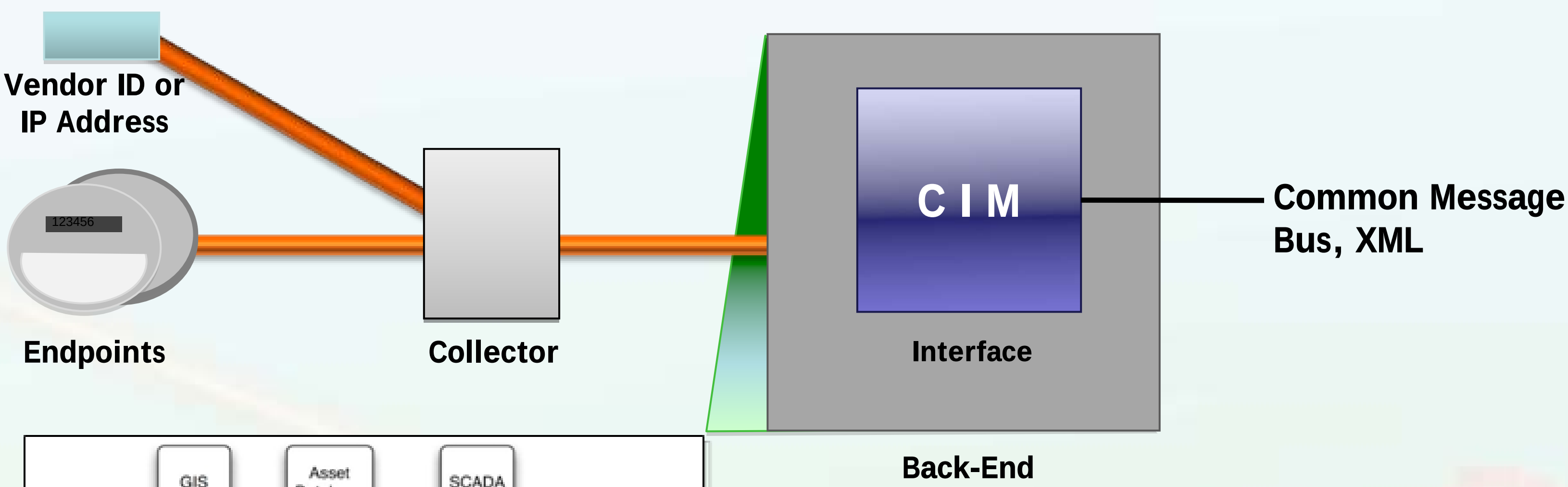


CIM – Common Information Model

CIM – IEC61968-9

PRO – Universal, Loosely Coupled, Interoperability from T&D to Meters to Thermostats
Any Vendor System Can Comply By Adding Interfaces to Back-End
No Loss of Invested Capital
Can Support IP or Non-IP Networks

CON – Still Under Definition; Mitigation: Multi-Speak Available Now



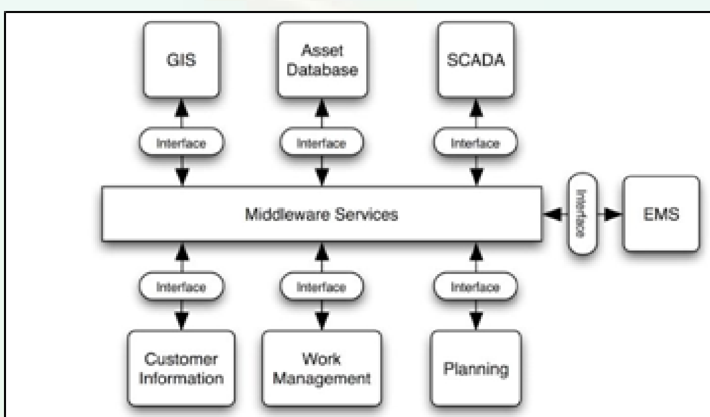


Figure 5.2 Enterprise Application Bus model for inter-application communication

Evolutionary Internet Protocol Roadmap

TCP – Added to 'IP' is TCP/IP (OSI Layer 4)

- TCP provides for guaranteed delivery at the expense of many round trip messages.
- Most vendor's systems already provide this functionality without the need for added overhead.
- In a good delivery environment TCP can cost as many as 11 transactions to deliver a single data message.

IPv6 Can Add 40 bytes to a Message and 11 Transactions

Raw Min Transfer at 50 kb/s Assumed Bit Rate			TCP		
Packet	Bytes	Time(ms)		Bytes	Time
Poll	12	1.8	SYN	60	9.4
Response	16	4.5	SYN, ACK	58	11.0
			ACK	50	9.8
			PSH (poll), ACK	62	11.6
			ACK	50	9.8
			PSH (response), ACK	66	12.3
			ACK	50	9.8
			FIN, ACK	50	9.8
			ACK	50	9.8
			FIN, ACK	50	9.8
			ACK	50	9.8
Transaction Bytes /Time ms	28	**6.3**		596	**113**
Number of Transactions	**2**			**11**	
Eff. Bit Rate	**35.5Kb/s**			**1.98Kb/s**	
Impact Capacity/ Latency	**0**			**18 X**	

POLL Request Message	
Poll message (assumed):	
Housekeeping info	2 bytes
Status & Command	2 bytes
Endpoint ID MAC	4 bytes
CRC 32	4 bytes
	12 bytes

TOU Meter Read Response Message Delivered Payload	
Assume:	
Housekeeping info	2 bytes
Includes kWh	3 bytes
Voltage	1 bytes
Status	2 bytes
Endpoint ID MAC	4 bytes
CRC32	4 bytes
	16 bytes

Data Rate & Hardware Latency Assumptions:
2 ms processing delay for each action (Xmit VCO settling and receiver CRC decode)
50 kb/s data rate

Why Not Just Increase Data Rate By 18X

Reduction in link margin occurs when receiver bandwidth is increased so that it can “HEAR” a higher data rate signal.

This is because it hears more noise but the signal power has not increased.

This is Called Signal to Noise Ratio, SNR

Reduction in SNR = 10 Log (Reduction in BW)

13 dB = 10 Log (2/36)

- This is the same as reducing a 1 Watt transmitter to 50 mW
- This increases collectors required by approximately 5X
- This reduces the number of redundant mesh paths by 5X

No Use-Case From NIST Workshop Required IP To Function

IP PROTOCOL IMPACT ON AMI USE-CASES

AMI Use Case	RAW Performance One Meter Baud/Latency	Performance If IP Via Proxy Or CIM	Performance If TCP/IP	Raw Vs TCP/IP Required Capacity	Latency if Collector to Backend is 100 ms
TOU Hourly Read – Single Ping	**36 kb/s / 6.3 ms**	**No Increase**	**2 kb/s / 113 ms**	**18X**	**1.24 s**
Demand Response					
Load Shed					
Outage Management					
Real Time Data					
Firmware Download					
Bidding Into Market					
Daily Read					
Outage Report					
Phasor Data					
PHEV					
Rooftop PV					
Islanding					
Managing Intermittence of DER					
Grid Self-Healing					
Changing Intervals					
Ping Meter Over The Air					

Numbers based on prior examples' assumptions.

Evolutionary Internet Protocol Roadmap

ROUTING

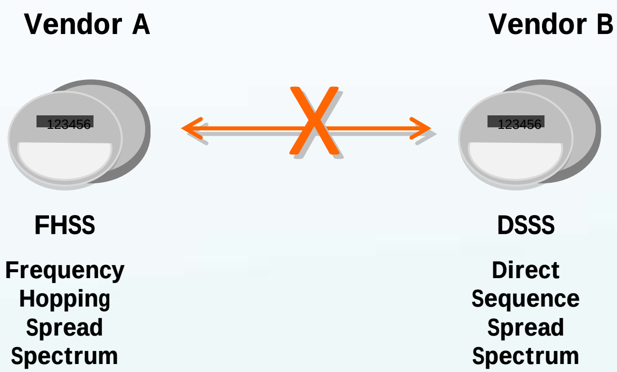
- **All Vendor's Systems Already Provide Routing**
- **Even Vendors That Use UDP Have Patented Custom Routing Algorithms. For example, Cisco Uses Custom Protocols on its Networks.**
- **The Temporal Coherence at 900mHz is 100 mS – the RF Environment Changes Radically, the Internet Protocol is Not Designed for That**
- **Common RF Design Practice is to Provide Macro Diversity, Whereby Multiple Collectors Can Hear an Endpoint; this is Contrary to IP Practice.**

APPLICATIONS

- **Poorly coded applications can provide an opportunity for malicious attacks**
- **Many flaws have been found in PC browsers and operating systems (and new ones are being found every day) which provide an opportunity for hackers.**
- **What are the implications of meters being hacked…and malware being installed.**
- **Meters Are Real Time Devices - if An Application consumes a Resource, the Meter Could Suffer Erroneous Readings - Apps Will Need 100% Isolation.**
- **This Needs to be Studied Very Carefully Including Testability, Warranty & Liability – Who is Responsible for a Bad "App".**

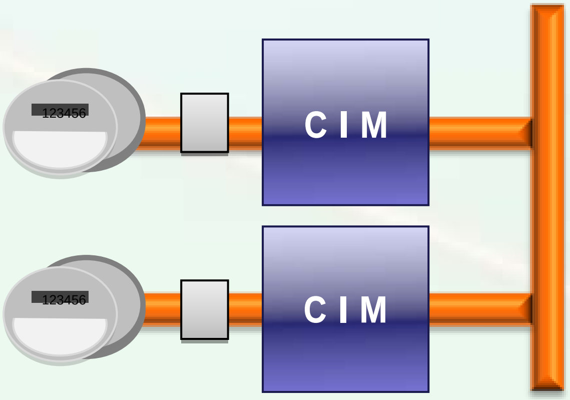
Common Public Misconception

Internet Protocol TCP/IP Will NOT Provide Endpoint "Swap-ability" – and It Will NOT Provide Common Data Description



Tower of Babel By Pieter Bruegel

CIM Solves The Second Issue



CIM Solves Issues that IP Does Not

Utility System Challenges Vs Consumer Products

- ***20+ Year Life***
- ***-40 To 85° C Operation***
- ***Tolerate Disasters***
- ***Commoditized Pricing***
- ***Never Re-Visit Endpoints in the Field***
- ***Can't Change the Meter Location if it Has a Bad Signal***
- ***Millions Have to Cooperate***
- ***Spread Over Tens of Thousands of Miles, Not 3 or 4 Nodes in a Home***

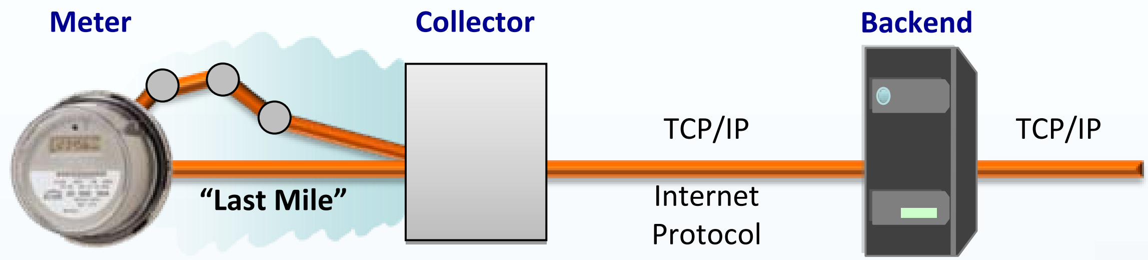
Vendor Solutions Are Customized to Meet These Challenges – Not to Lock Participants Out of a Market.

Vendors Have Worked on These Technical Challenges for the Last 20 Years (Evolution).

Tactics to Make Real AMI Solutions Have Just Become Proven in the Last 24 Months.

Not One Solution Worked exactly the Way the Design Teams Envisioned in the Field - Paper Designs Must Be Field Tested In Volume.

Don't Throw the Baby Out with the Bath Water



- No "Available" Standard Exists Today for the "Last Mile" Cloud; Many Proposals are in the Works, But Untested
- "Appropriate" - Before NIST Approves a Standard It Should Be Tested in the Field in the Use Case it Will Serve
  Large IOU RFQs Typically Require 1M Units in the Ground or 100K Unit Field Trial
- Diversity of PHY's Support the DOE Goals of Redundancy, Disaster Recovery and Protection of US Grid
- Thousands of Man-Years of Engineering and Field Experience in Existing Systems and New Features Under Development, That are Not Part of a Standard.

		Electric Units	Electric AMI	Field Time	
Power Line Carrier	Hunt	5.8M	1.9M	13 Yr	PLC, Low Baud
	TWACS	12.0M	0.0M	13 Yr	PLC, Mid Baud
	Cannon	1.2M	1.2M	13 Yr	PLC, Mid Baud
Radio	Cellnet	8.9M	0.2M	13 Yr	DSSS
	FlexNet	1.6M	1.6M	9 Yr	PCS, Licensed
	Elster	2.5M	2.5M	10 Yr	FHSS
	Itron	32.0M	0.1M	22 Yr	FHSS
	Silver Spring	0.3M	0.3M	8 Yr	FHSS

- SOLUTION: Use of a Standard Practice Proxy Server or CIM Can Make ANY of These Systems Internet Protocol Compatible
- Avoids: Obsolescence, Technology Risk, Stranded Capital, Delay to "Shovel Ready" and IP Patent Issues.

Evolutionary Internet Protocol RoadMap

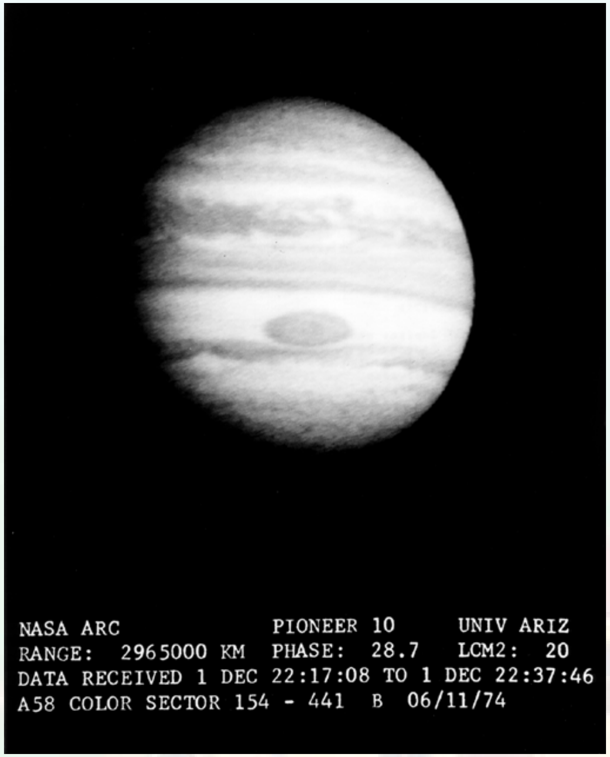
Utilities have full control of the systems that are deployed on their behalf. Interoperability of a grid is done at connect points that each utility controls and defends. Connection from one endpoint at one utility to an endpoint in another utility must be controlled and managed by each utility.

Revolutionary: "IP End-to-End," All Forms of the IETF 2734 RFCs

Recommend: Caution, Small Steps, Volume Field Trials of Use Cases (Like Outage Management)

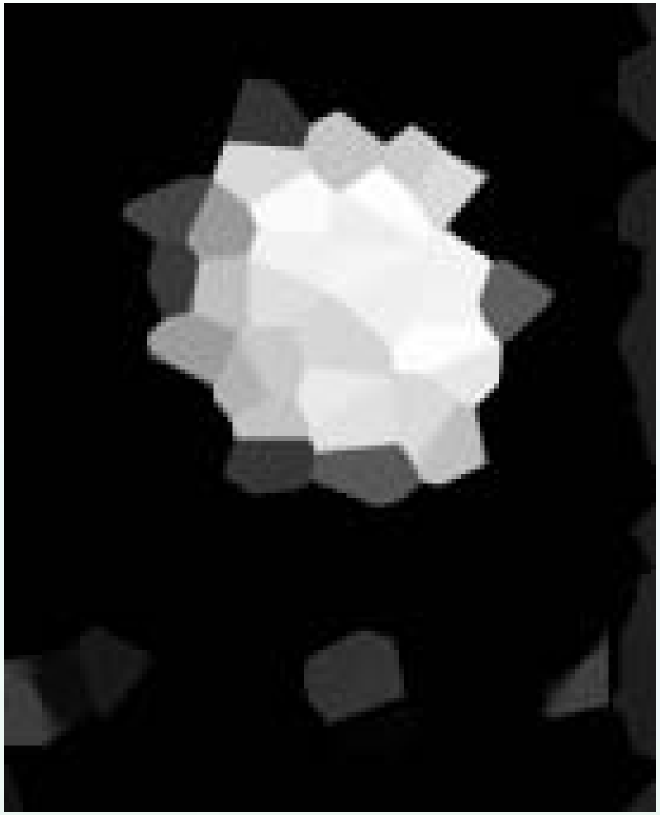
EXAMPLE: The image on the right was delivered from a NASA server to my browser in about 2 seconds.

This is an example of a great IP application.



If IP was mandated "At The Endpoint" to capture the original image, the spacecraft could have flown past the target before the capture was complete.

Sometimes specialized hardware and protocols are necessary.



Satellite transmission over TCP/ IP (simulation)

DON'T LET THE SMART GRID REVOLUTION KILL TECHNIQUES THAT ARE KNOWN TO WORK

EVOLVED SOLUTIONS CAN BE TESTED IN THE CRUCIBLE OF FIELD PERFORMANCE.

IS A STORM COMING? – THERE ARE 2136 IP SMART GRID PATENTS & PATENTS PENDING FILED WITH THE PTO

REVOLUTION IS RISKY, THERE ARE UN INTENDED CASUALTIES - LETS SPEND THE DILIGENCE TO GET IT RIGHT AND MINIMIZE THE REGRETS.

INTERNET PROTOCOL & OSI (OPEN SYSTEMS INTERCONNECTION)	
LAYER	**LAYER DESCRIPTION**
Client - Application wants to talk to an Endpoint.	
7 Application	Application wants to talk to an Endpoint. For example, perform a demand read of a meter
6 Presentation	Responsible for formatting or further processing (if necessary).
5 Session	Socket Interface; software library "Open A Socket" (e.g. socket to socket in Linux) - I want to write this block of data to the host at this IP address.
4 Transport	TCP (Transmission Control Protocol) - retries & communication verification & insured data order - provides a perfect serial data link UDP (User Data Protocol) - no guaranteed delivery of data
3 Network	IP (Internet Protocol) - IPv4, 32 bit address - IPv6, 128 bit address - no guarantee of delivery of data, no guarantee of order or repeated data - fragments big packets to pass over links with a MTU smaller than the original size. - sends/receives *blocks* of data ARP (address resolution protocol) maps to IP to Ethernet address
2 Data Link	e.g. 802.3, 802.11, 803.5 (Ethernet is layer 1 & 2; 802.3 NIC layer 2). Preamble and Frame address fields & error detection
1 Physical	e.g. Manchester encoding of data at +/-10v levels;
Radio Frequency WAN	

Packet Performance
The opposite page table shows the number of bytes and times to perform a poll and to receive a response using various packet types: RAW, IP, UDP, TCP and HTTP
RAW and UDP are connectionless and do not guarantee packet delivery or status
TCP and HTTP are connected streams and do provide for packet status