The Internet of Things
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Challenges of IoT

What is the Internet
What did Tim Berners-Lee develop?
What are "Things"?
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Overview

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- What is the Internet?

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- What are "Things"?

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- What is the Internet?
- What are "Things"?
- Why does one need the other?

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Origin of term "Internet of Things"

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Origin of term "Internet of Things"

- Peter T. Lewis -1985

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  "the integration of people, processes and technology with connectable devices and sensors to enable remote monitoring, status, manipulation and evaluation of trends of such devices."

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  Proctor and Gamble presentation; RFID use in supply chain management

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What is the Internet?

- Started in about 1950s (USA, DARPA)

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- Started in about 1950s (USA, DARPA)
- Goal was to have a robust communications network that could function with pieces missing

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- A "network of networks" (*inter*net(work))

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Before the Internet; phone network

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Before the Internet; phone network

- Telegraph began in 1830's

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Before the Internet; phone network

- Telegraph began in 1830's
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Before the Internet; phone network

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- Point-to-point connection requires switches

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Before the Internet; phone network

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- Point-to-point connection requires switches
- Connection is maintained for the duration of the call

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How does the Internet work?

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How does the Internet work?

- Every unique *host* has an address

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- Countries and organizations have banks of addresses which can be assigned

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  A message can consist of several packets

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  All packets don't need to travel the same route

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  A message can consist of several packets

  All packets don't need to travel the same route

  The packets don't need to arrive in the correct order

EVENTUALLY

Cyanide and Happin

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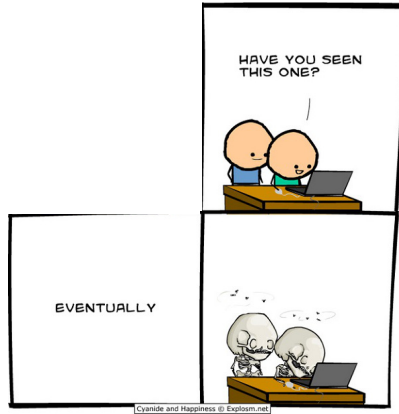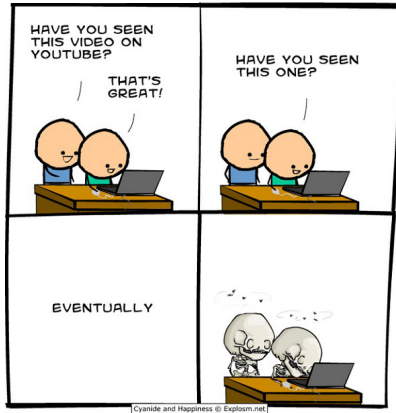Remote sensing before the Internet
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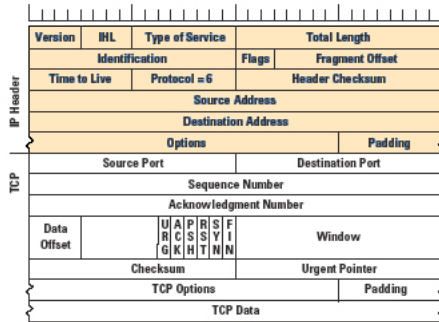Remote sensing before the Internet
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How many Internet addresses are there?

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- The version of *internet protocol* in current use is IPV4

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- IPV4 uses 32 bit addresses

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- Useful fact: $2^{10} = 1024 \approx 10^3$

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  $2^{32} = 4 \times 2^{10} \times 2^{10} \times 2^{10} \approx 4 \times 10^9$

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  About 4 billion IPV4 addresses

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  About 4 billion IPV4 addresses

  There are over 7 billion people on Earth

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Address exhaustion

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Address exhaustion

- As early as the 1980s it was apparent the address space would get used up

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Address exhaustion

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  NB: Bill Gates once said 640KB of memory should be enough for anyone

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  When I started programming in the late 70s the **mainframe** *had 500KB of memory*

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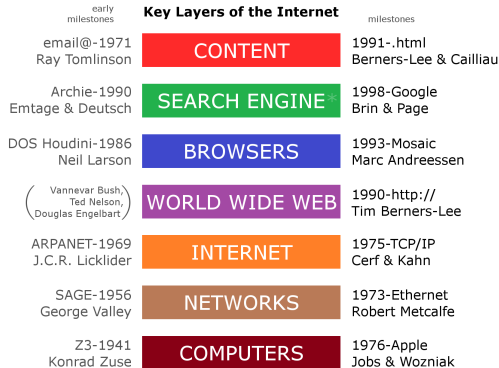Remote sensing before the Internet
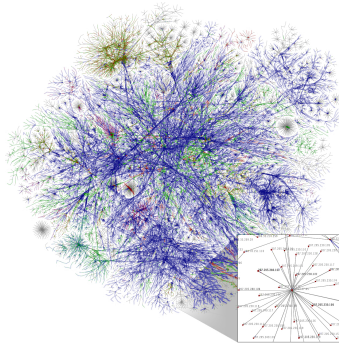Software

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- In the early 1990s, Tim Berners-Lee developed the World Wide web, which led to massive expansion beyond the original audience

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early milestones	Key Layers of the Internet	milestones
email@-1971 Ray Tomlinson	CONTENT	1991-.html Berners-Lee & Cailliau
Archie-1990 Emtage & Deutsch	SEARCH ENGINE*	1998-Google Brin & Page
DOS Houdini-1986 Neil Larson	BROWSERS	1993-Mosaic Marc Andreessen
Vannevar Bush, Ted Nelson, Douglas Engelbart	WORLD WIDE WEB	1990-http:// Tim Berners-Lee
ARPANET-1969 J.C.R. Licklider	INTERNET	1975-TCP/IP Cerf & Kahn
SAGE-1956 George Valley	NETWORKS	1973-Ethernet Robert Metcalfe
Z3-1941 Konrad Zuse	COMPUTERS	1976-Apple Jobs & Wozniak

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Other option; MAC address

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Other option; MAC address

- Any internet connected device has a MAC address

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Other option; MAC address

- Any internet connected device has a MAC address
  Media **A**ccess **C**ontrol

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  unique (assigned by manufacturer)

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  48 bits

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  That means there are $2^{16} \approx 64000$ MAC addresses for every IPV4 address

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Other option; MAC address

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  Why not use them instead?

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Why MAC addresses won't work

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Why MAC addresses won't work

- Remember: *assigned by manufacturer*

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Why MAC addresses won't work

- Remember: *assigned by manufacturer*
- How do you know where to route a message if the address is not geographical?

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  That would be like trying to deliver mail to "Jane Elizabeth Smith born May 12, 1975"

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- Why not use a lookup table?

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- Why not use a lookup table?

  Remember there are $2^{48} \approx 2^8 \times 10^{12}$ MAC addresses

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  If a router can search 1 billion (i.e. 10^9) addresses per second, a complete lookup table search would take about $2^8 \times 10^3$ seconds (or about 71 hours)

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- **This won't work; addresses have to contain routing information**

Solution: IPV6

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Solution: IPV6

- A new internet protocol, IPV6, has been created

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Solution: IPV6

- A new internet protocol, IPV6, has been created
- It uses 128 bit addresses

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Solution: IPV6

- A new internet protocol, IPV6, has been created
- It uses 128 bit addresses

  That means there are $2^8 \times 10^{3^{12}} \approx 10^{38}$ addresses

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Solution: IPV6

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- It uses 128 bit addresses

  That means there are $2^8 \times 10^{3^{12}} \approx 10^{38}$ addresses
- Is that enough for the foreseeable future?

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Are there enough IPV6 addresses?

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Are there enough IPV6 addresses?

- The radius of the earth is about 6000 km or $6 \times 10^6 m$

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Are there enough IPV6 addresses?

- The radius of the earth is about 6000 km or $6 \times 10^6 m$

  That means its surface area is $4\pi R^2 \approx 70 \times 10^{12} m^2$

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- The atmosphere is about 100km thick, or $10^5 m$

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- The atmosphere is about 100km thick, or $10^5 m$

  Thus the volume of the atmosphere is about $10^{19} m^3$, or $10^{19} \times 10^9 = 10^{28} mm^3$

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- There are about 3×10^7 seconds in a year

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- There are about 3×10^7 seconds in a year

- **We could assign a new IPV6 address to every cubic
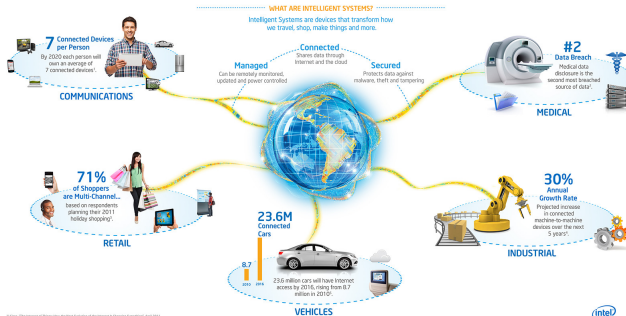 millimetre in the atmosphere for about 1000 years
  before exhausting them.**

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What are "Things"?

- Originally the internet was conceived to connect people to people

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- Early on, some saw it as a means of automation

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The first "thing" on the Internet?

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The first "thing" on the Internet?

Coke machine

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Coke machine
Carnegie-Mellon
University

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Coke machine
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The Carnegie-Mellon Coke machine

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The Carnegie-Mellon Coke machine

- (Circa 1982), switches in machine counted remaining stock

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- (Circa 1982), switches in machine counted remaining stock
- Machine could be queried using *finger* protocol

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The first "thing" on the World Wide Web?

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- Long before webcams, (early 1990s), a digital framegrabber took pictures every few seconds

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- Long before webcams, (early 1990s), a digital framegrabber took pictures every few seconds
- A web server posted the image to a web page

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- Long before webcams, (early 1990s), a digital framegrabber took pictures every few seconds
- A web server posted the image to a web page
- When a new pot was brewed, a feeding (actually, drinking) frenzy could occur

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Remote sensing before the Internet

Options included:

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Remote sensing before the Internet

Options included:

- Radio

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Remote sensing before the Internet

Options included:

- Radio
- Satellite

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Remote sensing before the Internet

Options included:

- Radio

- Satellite

- Dedicated phone line

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Remote sensing before the Internet

Options included:

- Radio

- Satellite

- Dedicated phone line

All specialized and relatively expensive, since "path" needs to be approved and/or created

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Remote sensing using the Internet

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Remote sensing using the Internet

- Wifi fairly ubiquitous

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Remote sensing using the Internet

- Wifi fairly ubiquitous
- Cellular possible in many more locations

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Remote sensing using the Internet

- Wifi fairly ubiquitous
- Cellular possible in many more locations
- Satellite internet possible as well

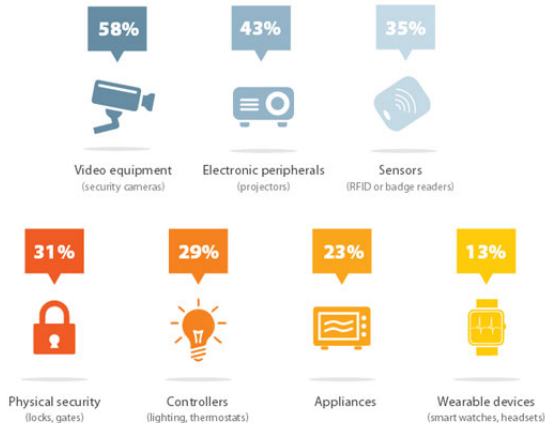Introduction
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Remote sensing using the Internet

- Wifi fairly ubiquitous
- Cellular possible in many more locations
- Satellite internet possible as well

Access to internet at each end is all that's required, since "path" between device and monitor is already established.
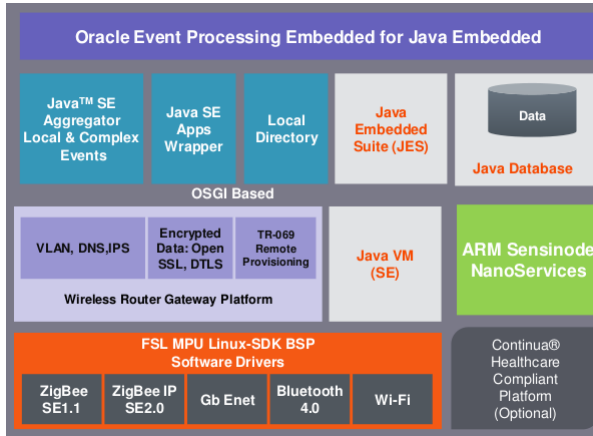
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Software

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Software

- Devices each need TCP/IP stack

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Security Applications
Home Automation Applications

Applications of IoT

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- Medical

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- Medical
- Security and safety

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- Medical
- Security and safety
- Home automation

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- Implanted devices

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Medical Applications

- Implanted devices

  pacemakers, insulin pumps

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- Implanted devices

  pacemakers, insulin pumps

  allows real-time remote monitoring and logging

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Medical Applications

- Implanted devices

  pacemakers, insulin pumps

  allows real-time remote monitoring and logging

  timed release of medication; e.g. chemotherapy, pain relievers, etc.

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  remote monitoring of security system, cameras, baby monitor/camera

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  remote monitoring of security system, cameras, baby monitor/camera

  pet/child tracking

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  remote monitoring of security system, cameras, baby monitor/camera

  pet/child tracking

- Auto

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  remote monitoring of security system, cameras, baby monitor/camera

  pet/child tracking

- Auto

  tracking of vehicle and components; e.g. stereo

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- Home

  remote monitoring of security system, cameras, baby monitor/camera

  pet/child tracking

- Auto

  tracking of vehicle and components; e.g. stereo

  real-time logging of "black box" status information

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TRANSPORT › AIRLINES

The Small
Canadian
Airline That
Already Has the
Flight-Tracking
System of the
Future

Marisa Garcia, Skift
@designerjet

May 08, 2014 9:00 am

The regional carrier First Air knows where its planes are at all times. First Air

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  environment monitoring and control

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  environment monitoring and control

  pet/child tracking

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  environment monitoring and control

  pet/child tracking

- Auto

  cloud based entertainment

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- Home

  environment monitoring and control

  pet/child tracking

- Auto

  cloud based entertainment

  reminders of maintenance; automatic appointment scheduling, diagnosis

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Challenges of IoT

Challenges of IoT

- Environmental

Challenges of IoT

- Environmental
- Security

Challenges of IoT

- Environmental
- Security
- Communication

Environmental challenges

Environmental challenges

- IoT devices are more complex

Environmental challenges

- IoT devices are more complex
- Devices get frequent upgrades

Security challenges

Security challenges

- Remote *monitoring* could be by anyone

Security challenges

- Remote *monitoring* could be by anyone
- Remote *control* ...!!!!!!

Communication

Communication

- Devices talking to a *server* or *user* is only the beginning

Communication

- Devices talking to a *server* or *user* is only the beginning
- Devices talking to *each other* will follow

Communication

- Devices talking to a *server* or *user* is only the beginning
- Devices talking to *each other* will follow
- What sort of language could allow for all kinds of devices to talk *to each other*?

The Semantic Web - Tim Berners-Lee

The Semantic Web - Tim Berners-Lee

"I have a dream for the Web [in which computers] become capable of analyzing all the data on the Web - the content, links, and transactions between people and computers. A 'Semantic Web', which makes this possible, has yet to emerge, but when it does, the day-to-day mechanisms of trade, bureaucracy and our daily lives will be handled by machines talking to machines. The 'intelligent agents' people have touted for ages will finally materialize."

The future?