

CSCI E-11

Class 11

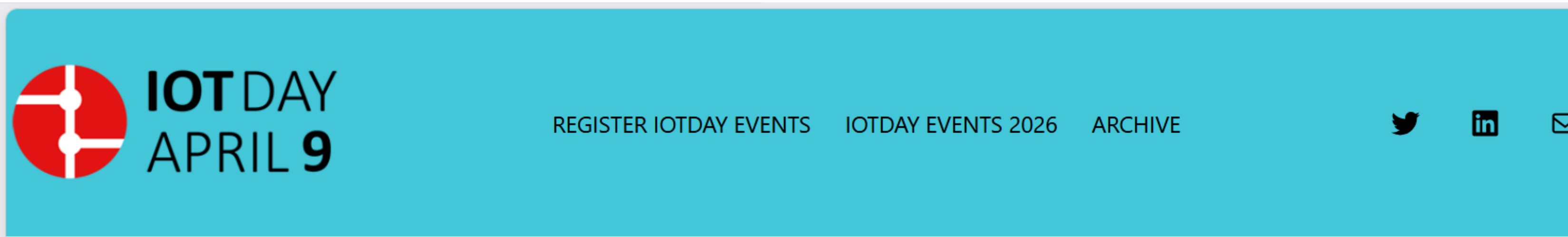
April 14, 2026

Introduction to IoT



Harvard
Extension School
HARVARD DIVISION OF
CONTINUING EDUCATION

Happy IoT Day (observed)!



IOTDAY THEME 2026: THE CONVERSATION WE NEED NOW

The death of IoT as a term has been proclaimed a number of times, still it is very much alive. As IoT is a horizontal operation tuned to the quality of data gathered from sensors and sensing it influences both the choice of connectivity as well as the environment in which analysis is taking place.

Predictions about IoT don't have a great track record.

Internet of Things (IoT) Advisory Board (IoTAB) Report

OCTOBER 2024

In 2014, the World Economic Forum and McKinsey and Company. projected that IoT, and adjacent technologies (analytics, cloud computing, big data, and ML/AL) would produce up to \$21.6 trillion of value for the global economy by 2022.¹¹

In 2021, McKinsey and Company. revised the IoT forecast downward by 42%, projecting global value of only \$5.5 to \$12.6 trillion, and not reaching those targets until 2030.¹² The revision was attributed to headwinds related to change management, cost, talent, and cybersecurity. Furthermore, other factors noted the slow market adoption of digitalization and cyber-resilience, particularly in large enterprises.

Even if we believe predictions, what do they mean?

2019:

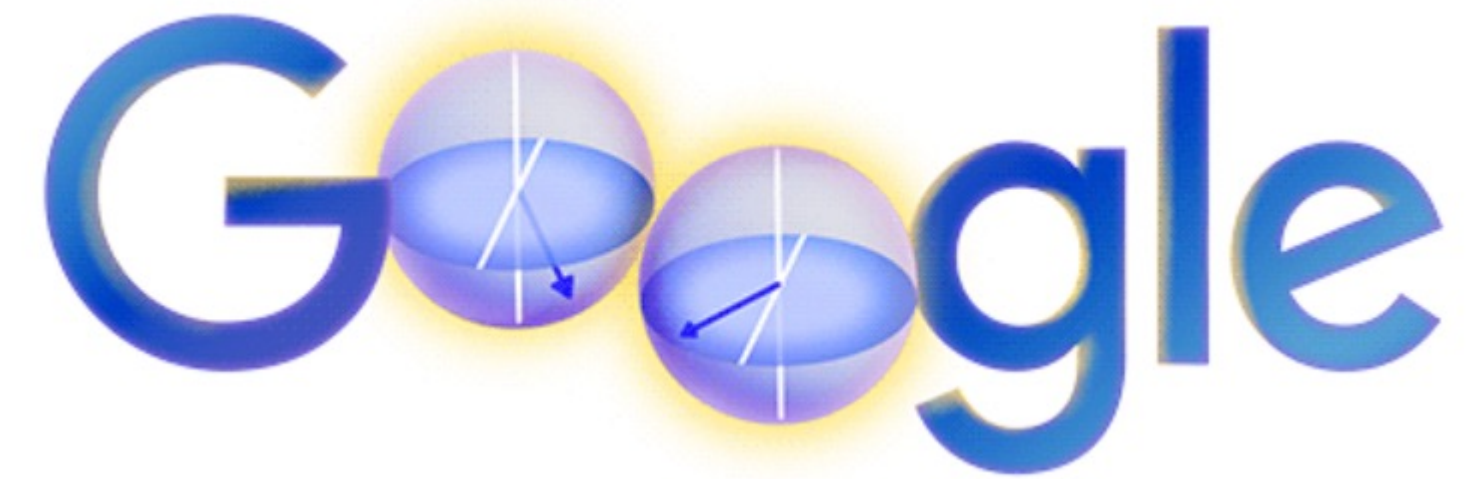
The Internet of Things (IoT) can mean different things to different people, but it undeniably involves many devices and a lot of data. A forecast by International Data Corporation (IDC) estimates that there will be 41.6 billion IoT devices in 2025, capable of generating 79.4 zettabytes (ZB) of data.

<https://infohub.delltechnologies.com/en-us/l/edge-to-core-and-the-internet-of-things-2/internet-of-things-and-data-placement>

2025:

IoT connections (billion)			
IoT	2025	2031	CAGR 2025-2031
Wide-area IoT	4.9	8.3	9%
Cellular IoT	4.5	7.8	10%
Short-range IoT	17.5	38.8	14%
Total	22.3	47.1	13%

Today is World Quantum Day!



**WORLD
QUANTUM
APRIL 14TH
DAY**

**WORLD QUANTUM DAY:
APRIL 14, 2026**

World Quantum Day is an annual celebration promoting public awareness and understanding of quantum science and technology around the world.

[CHECK THE EVENTS >>](#)

[SUBMIT YOUR EVENT >>](#)

Last Week’s Reading: Mirzadeh, et al.

GSM-Symbolic: Understanding the Limitations of Mathematical Reasoning in Large Language Models

Iman Mirzadeh[†] Keivan Alizadeh Hooman Shahrokhi*
Oncel Tuzel Samy Bengio Mehrdad Farajtabar[†]

Apple

Abstract

Recent advancements in Large Language Models (LLMs) have sparked interest in their formal reasoning capabilities, particularly in mathematics. The GSM8K benchmark is widely used to assess the mathematical reasoning of models on grade-school-level questions. While the performance of LLMs on GSM8K has significantly improved in recent years, it remains unclear whether their mathematical reasoning capabilities have genuinely advanced, raising questions about the reliability of the reported metrics. To address these concerns, we conduct a large-scale study on several state-of-the-art open and closed models. To overcome the limitations of existing evaluations, we introduce GSM-Symbolic, an improved benchmark created from symbolic templates that allow for the generation of a diverse set of questions. GSM-Symbolic enables more controllable evaluations, providing key insights and more reliable metrics for measuring the reasoning capabilities of models. Our findings reveal that LLMs exhibit noticeable variance when responding to different instantiations of the same question. Specifically, the performance of all models declines when only the numerical values in the question are altered in the GSM-Symbolic benchmark. Furthermore, we investigate the fragility of mathematical reasoning in these models and demonstrate that their performance significantly deteriorates as the number of clauses in a question increases. We hypothesize that this decline is due to the fact that current LLMs are not capable of genuine logical reasoning; instead, they attempt to replicate the reasoning steps observed in their training data. When we add a single clause that appears relevant to the question, we observe significant performance drops (up to 65%) across all state-of-the-art models, even though the added clause does not contribute to the reasoning chain needed to reach the final answer. Overall, our work provides a more nuanced understanding of LLMs’ capabilities and limitations in mathematical reasoning.

1 Introduction

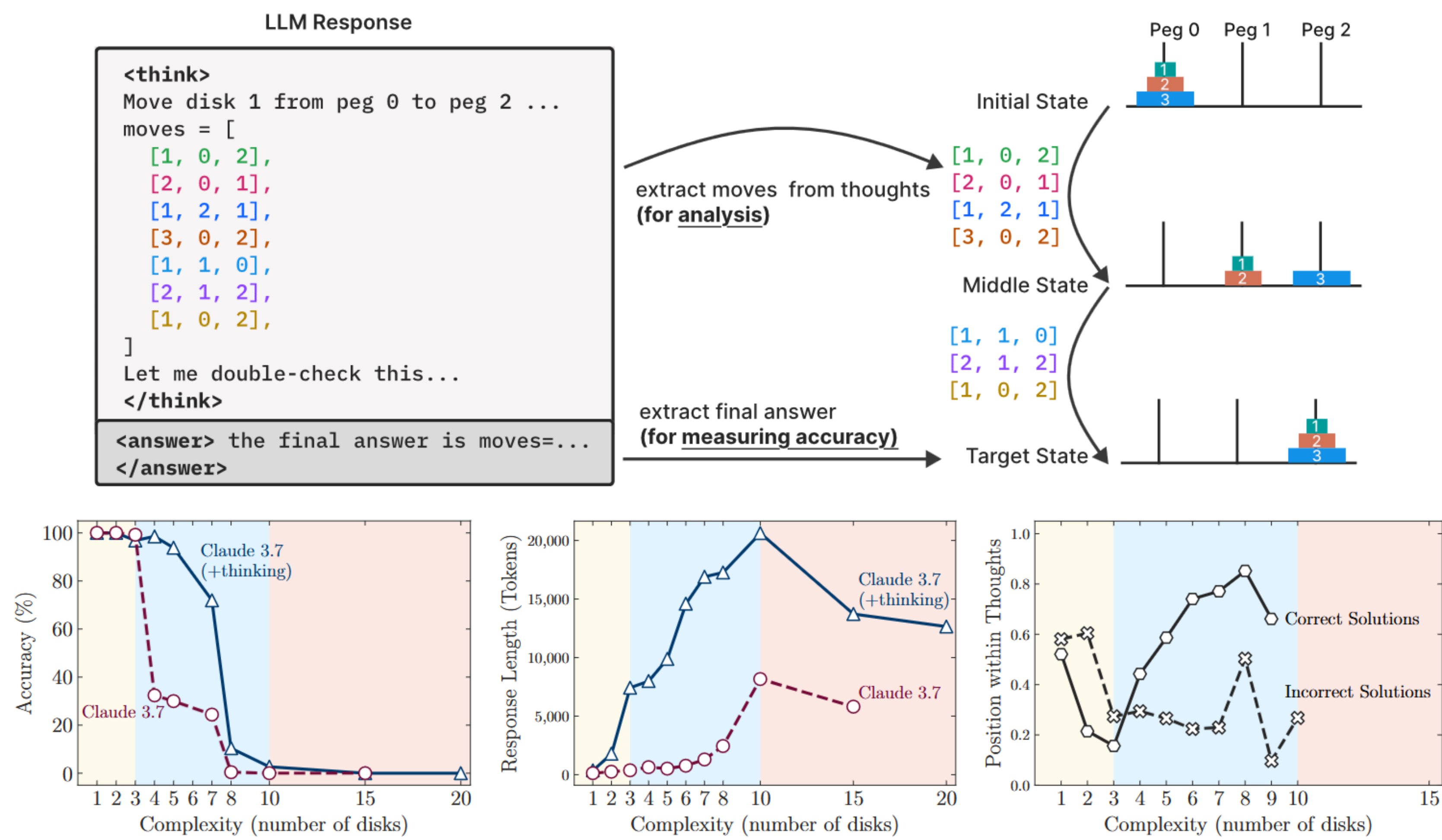
Large Language Models (LLMs) have demonstrated remarkable capabilities across various domains, including natural language processing, question answering, and creative tasks (Gunter et al., 2024; OpenAI, 2023; Dubey et al., 2024; Anil et al., 2023; Abdin et al., 2024; Rivière et al., 2024). Their potential to perform complex reasoning tasks, particularly in coding and mathematics, has garnered significant attention from researchers and practitioners.

However, the question of whether current LLMs are genuinely capable of true logical reasoning remains an important research focus. While some studies highlight impressive capabilities, a closer examination reveals substantial limitations. Literature suggests that the reasoning process in LLMs

^{*}Work done during an internship at Apple. [†]Correspondence to {imirzadeh, farajtabar}@apple.com.

Continuing the conversation about LLM reasoning...

The Illusion of Thinking: Understanding the Strengths and Limitations of Reasoning Models via the Lens of Problem Complexity



Others think that LLMs are already revolutionizing mathematics.



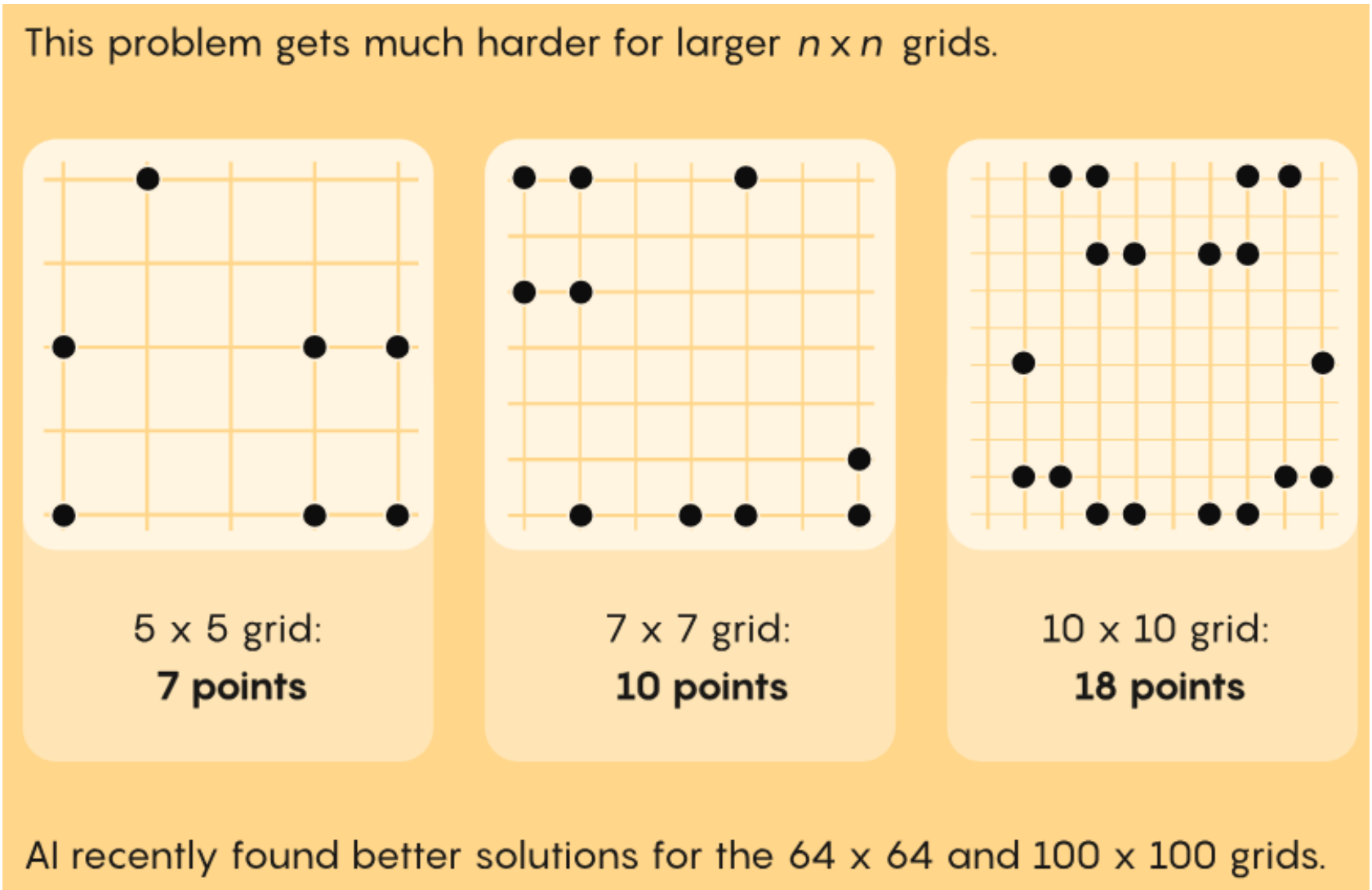
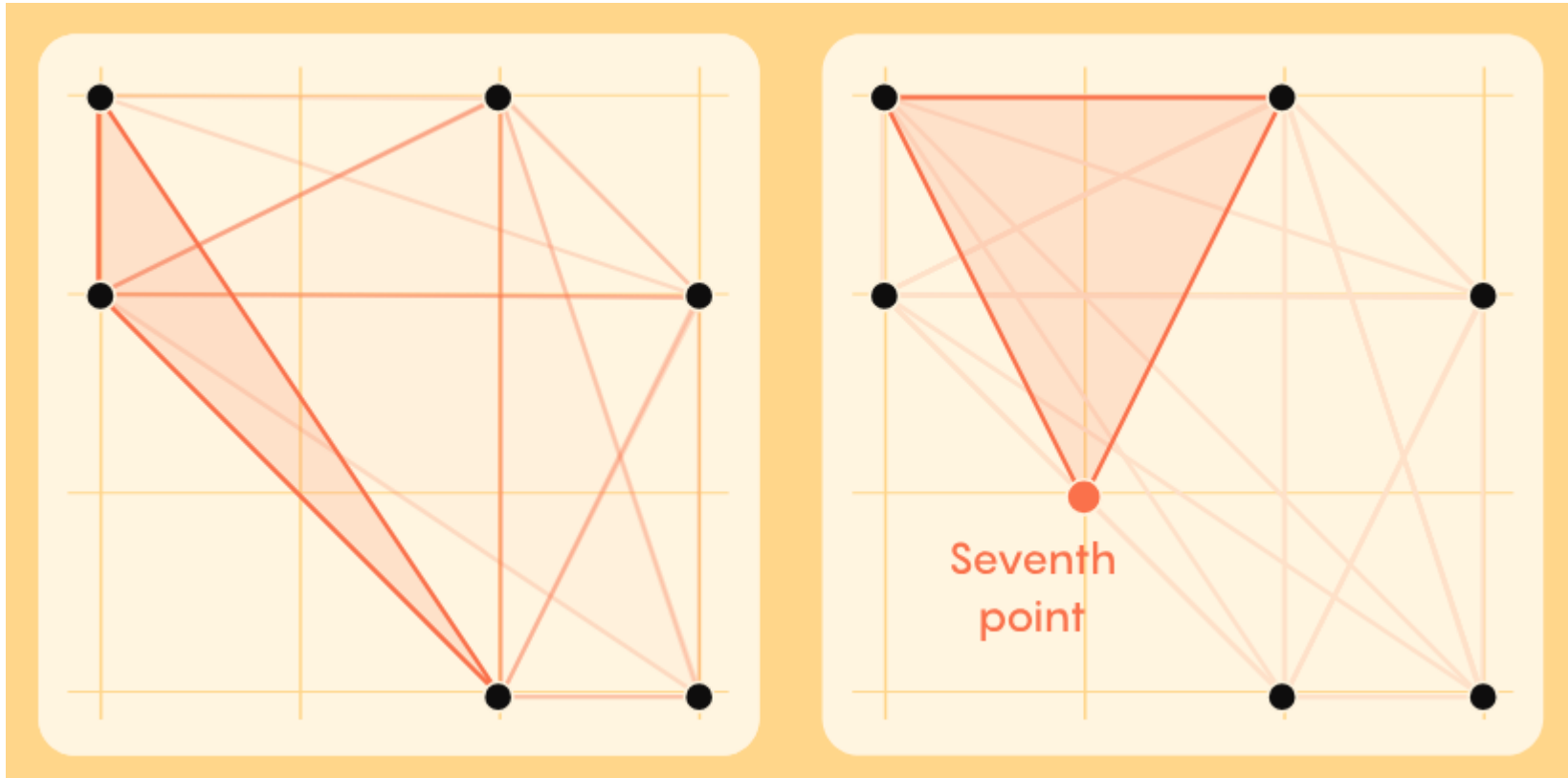
PhysicsMathematicsBiologyComputer ScienceTopicsArchive



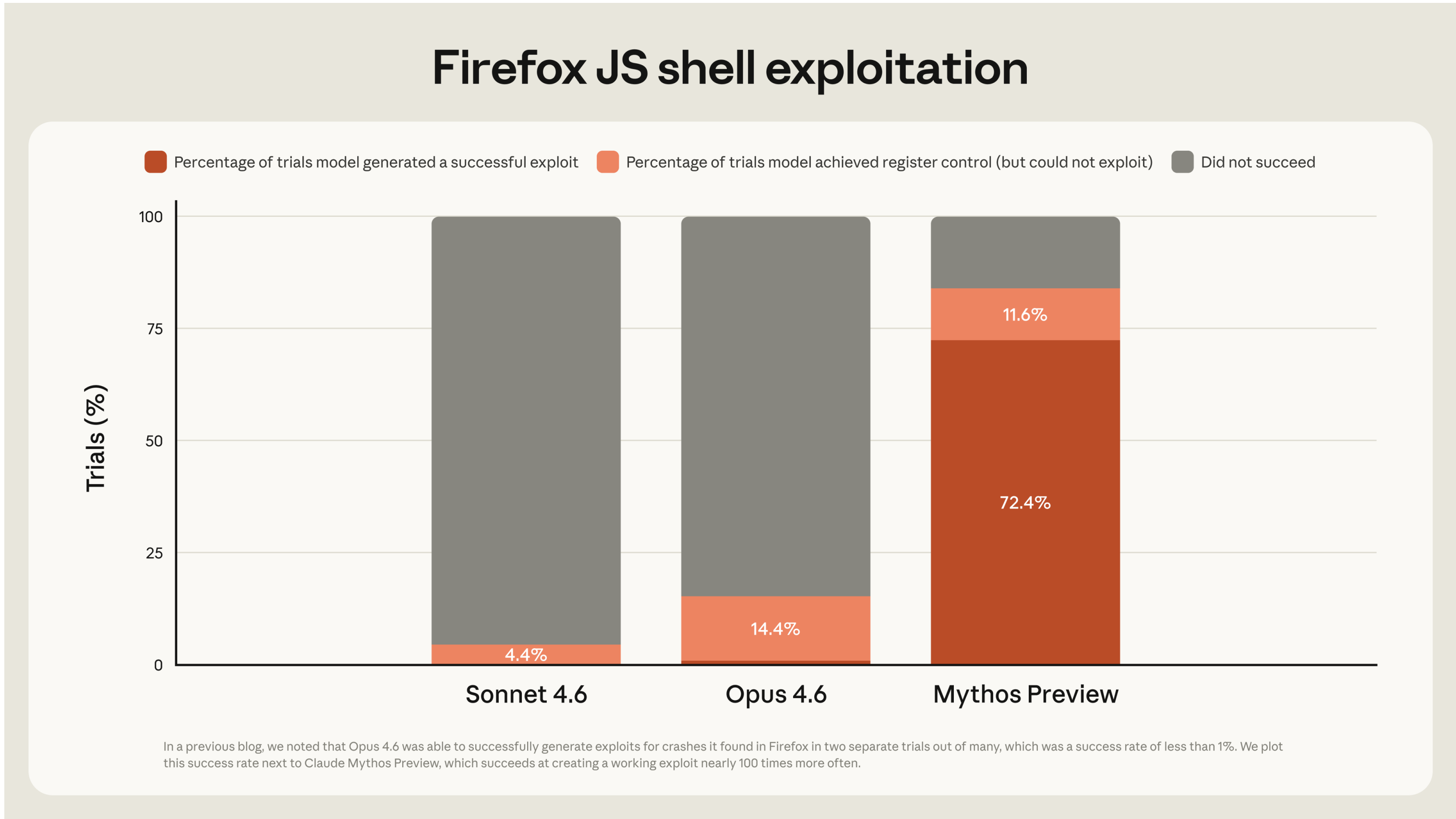
FOUNDATIONS OF MATHEMATICS
The AI Revolution in Math Has Arrived
Konstantin Kakaes
Contributing Writer
April 13, 2026
1

AI is being used to prove new results at a rapid pace. Mathematicians think this is just the beginning.

What’s the maximum number of points you can draw on an $n \times n$ grid without forming an isosceles triangle?



News of the week: Anthropic's Mythos and Project Glasswing



ANTHROPIC
System Card:
Claude Mythos
Preview
April 7, 2026

<https://red.anthropic.com/2026/mythos-preview/>

The media jumped on and amplified the Mythos story.

AI-boosted hacks with Anthropic’s Mythos could have dire consequences for banks

By A.J. Vicens and Raphael Satter

April 13, 2026 2:11 PM EDT · Updated 21 hours ago



Why Anthropic’s new model has cybersecurity experts rattled

The company says it has built its most dangerous model yet. Can its coalition of internet companies fix the internet before others catch up?



Casey Newton
Apr 7, 2026 — 9 min read

Claude Mythos and Project Glasswing: why an AI superhacker has the tech world on alert

Published: April 13, 2026 4:02am EDT

The New York Times

OPINION

THOMAS L. FRIEDMAN

Anthropic’s Restraint Is a Terrifying Warning Sign

April 7, 2026

The Atlantic

Claude Mythos Is Everyone’s Problem

What happens when AI can hack everything?

By Matteo Wong

This is not the first time an LLM company said its model was too powerful to release.

TC TechCrunch

Latest Startups Venture Apple Security AI Apps

OpenAI built a text generator so good, it's considered too dangerous to release

Zack Whittaker
9:17 AM PST · February 17, 2019

A storm is brewing over a new language model, built by non-profit artificial intelligence research company OpenAI, which it says is so good at generating convincing, well-written text that it's worried about potential abuse.

<https://techcrunch.com/2019/02/17/openai-text-generator-dangerous/>

Mythos seems capable but there may be less than meets the eye.



AI Security Institute

@AISecurityInst

In 2023 the best models could barely complete beginner-level cyber tasks. Today, our evaluation of **Mythos** Preview shows that it – and potentially future models – could be directed to autonomously compromise small, weakly defended, and vulnerable systems if given network access.

Red Hat Blog

Navigating the Mythos-haunted world of platform security

April 8, 2026 | [Gunnar Hellekson](#), [Jeremy West](#), [Subhro Kar](#), [Keith Grant](#) | 7-minute read

Within the Red Hat product ecosystem, almost none of these recently discovered bugs can cause a service-impacting issue. Annoying? Certainly. Business-destroying? Not so much.

tom's **HARDWARE** premium

[Tech Industry](#) > [Artificial Intelligence](#)

Anthropic's Claude Mythos isn't a sentient super-hacker, it's a sales pitch — claims of 'thousands' of severe zero-days rely on just 198 manual reviews

News Analysis By [Jon Martindale](#) published April 10, 2026

Many of the "thousands" of bugs and vulnerabilities it found are in older software, or are impossible to exploit.

The Internet of What?

Early example: The CMU Coke machine

Originally connected to the timesharing machine in the 1970s

EMPTY	EMPTY	1h	3m
COLD	COLD	1h	4m

- > In 1992, a second year graduate student and a full time staff member
- > of the CMU CS department decided to re-connect the coke machine to the
- > internet. The new Coke Machine Interface passively senses the
- > presence of bottles in the machine by the state of the "empty" light
- > for each column. The status of the nearby M&M machine is also
- > monitored. The new Coke Machine Interface is based on home-brew
- > optical isolators designed by John Zsarnay before he left CMU in 1991.
- > The new Coke Machine Interface resides on a PC-XT class machine whose
- > host name is COKE.ELAB.CS.CMU.EDU at IP address 128.2.209.43.

```
The "Only" Coke Machine on the Internet

Hi, I'm the CMU CS Department Coke Machine.  A lot of folks have
written a quite a bit about me in the last couple of years, and most
of them can tell you more about the history of me and my family than I
can.  Before I worked here, my Mom, and I think her Pop (heh heh :-)
used to sell sodas to the folks in the Computer Science Department.
In fact, my family has been here longer than most of the students, and
even a lot of the faculty.  We moved to the third floor of the
computer science building (Wean Hall) in the 70's.  I still sell Coke
in bottles, but they're big 20 oz plastic things these days.  They go
for 50 cents each, which I guess isn't too bad considering inflation.
And at least they don't break inside me any more like the glass ones
used to.  What a mess...

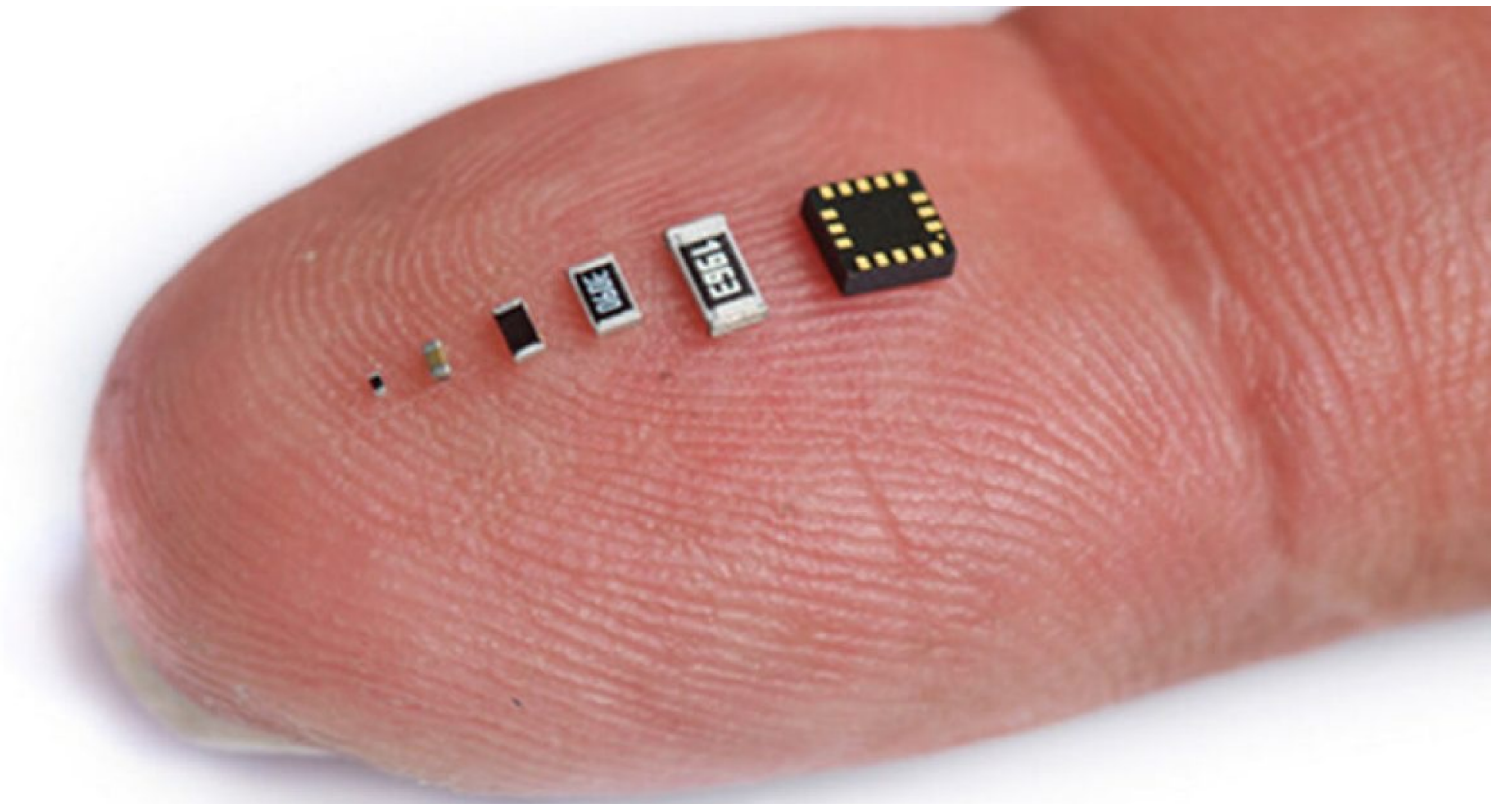
Tom Lane had the following to say about us:

> Since time immemorial (well, maybe 1970) the Carnegie-Mellon CS
> department has maintained a departmental Coke machine which sells
> bottles of Coke for a dime or so less than other vending machines
> around campus.  As no Real Programmer can function without caffeine,
> the machine is very popular.  (I recall hearing that it had the highest
> sales volume of any Coke machine in the Pittsburgh area.)  The machine
> is loaded on a rather erratic schedule by grad student volunteers.
>
> In the mid-seventies expansion of the department caused people's
> offices to be located ever further away from the main terminal room
> where the Coke machine stood.  It got rather annoying to traipse down
> to the third floor only to find the machine empty - or worse, to shell
> out hard-earned cash to receive a recently loaded, still-warm Coke.
> One day a couple of people got together to devise a solution.
>
> They installed micro-switches in the Coke machine to sense how many
> bottles were present in each of its six columns of bottles.  The
> switches were hooked up to CMUA, the PDP-10 that was then the main
> departmental computer.  A server program was written to keep tabs on
> the Coke machine's state, including how long each bottle had been in
> the machine.  When you ran the companion status inquiry program, you'd
> get a display that might look like this:
>
>
>          EMPTY    EMPTY    1h 3m
>          COLD      COLD     1h 4m
>
>
> This let you know that cold Coke could be had by pressing the
> lower-left or lower-center button, while the bottom bottles in the two
> right-hand columns had been loaded an hour or so beforehand, so were
> still warm.  (I think the display changed to just "COLD" after the
> bottle had been there 3 hours.)
>
```


1990: The Internet Toaster



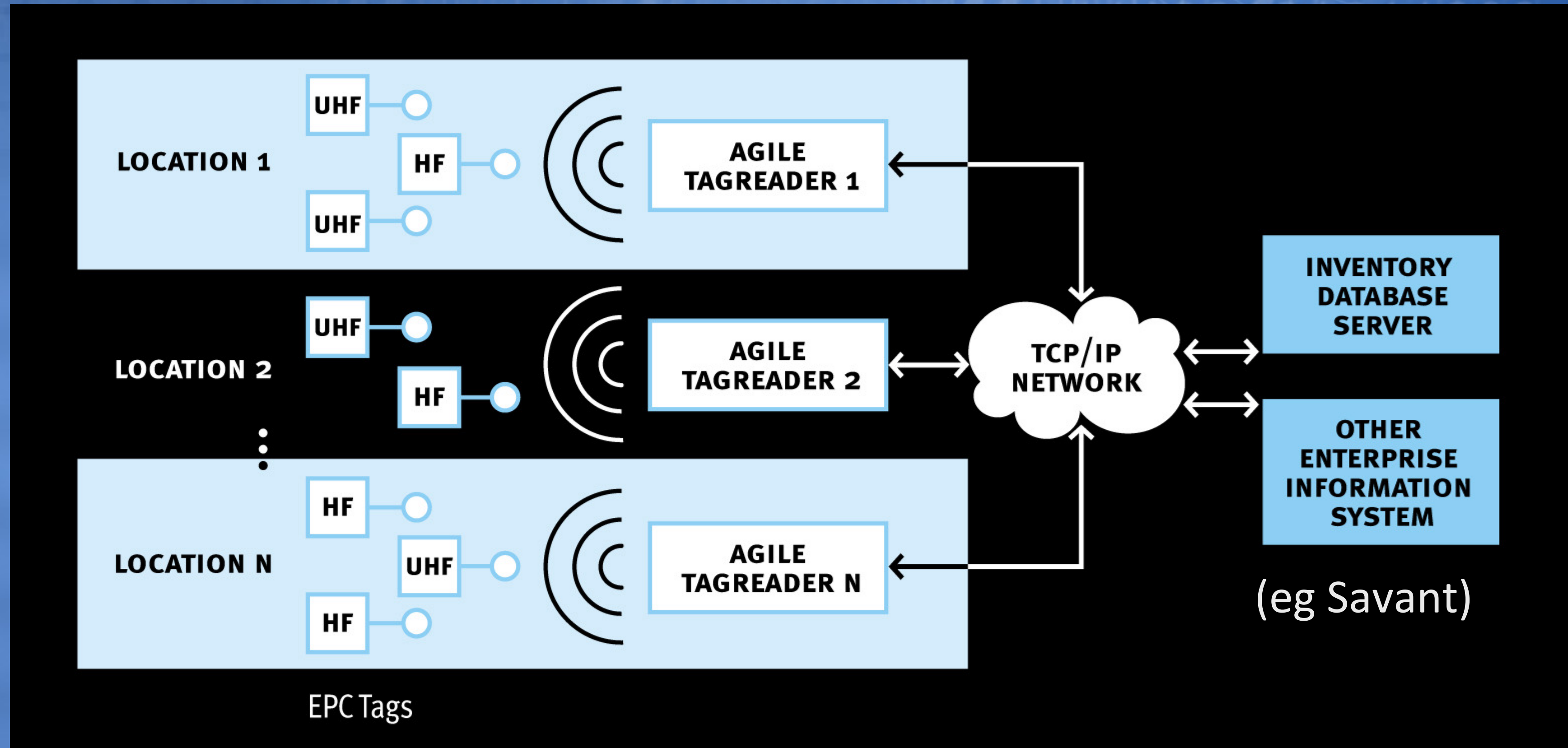
1999: Kevin Ashton, MIT Auto-ID Center, coins “Internet of Things”



<https://alchetron.com/Kevin-Ashton>

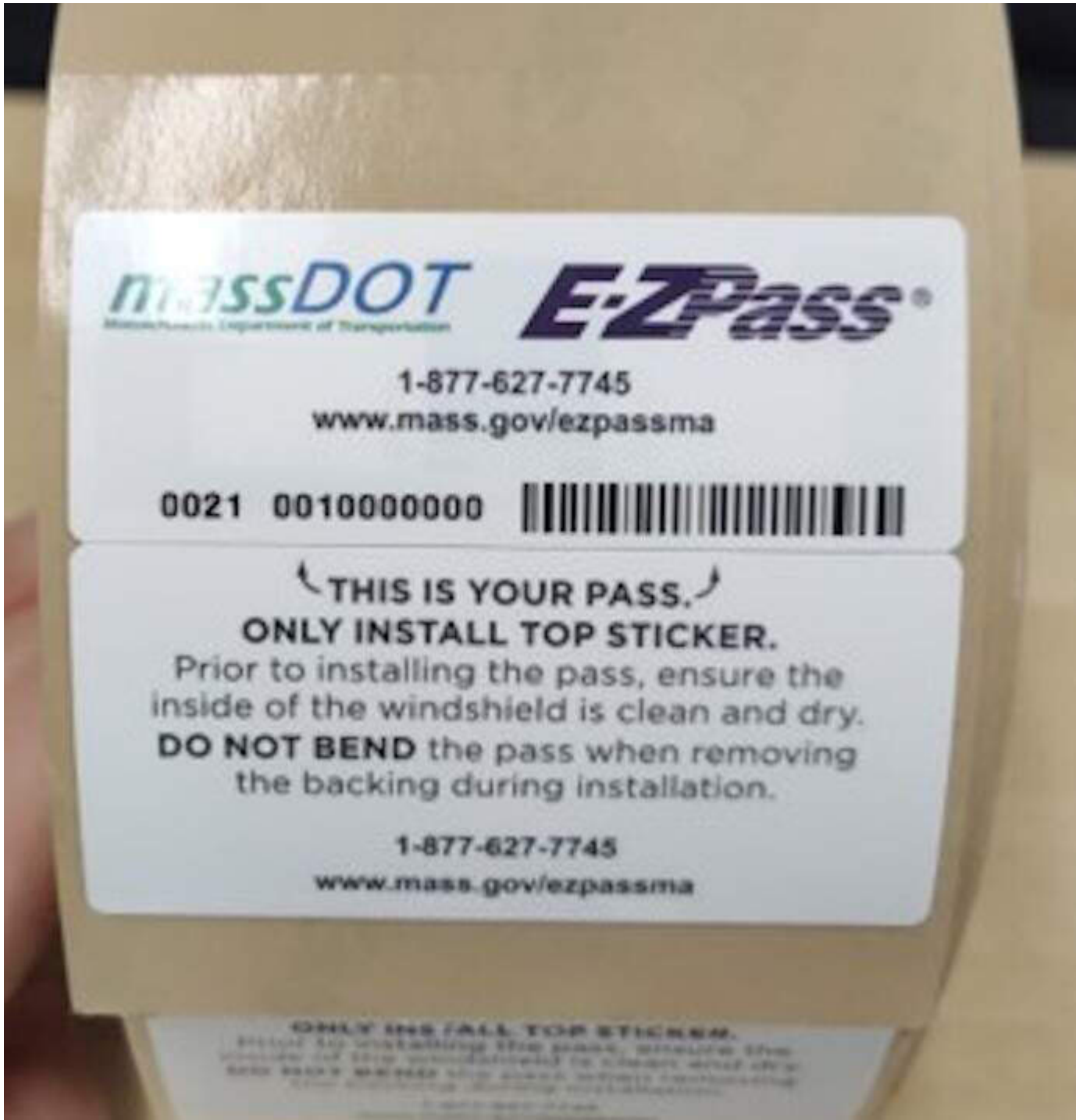


Elements of an RFID system



Four main elements: Tags, Readers, Antennas, and Network Systems

Examples of things.

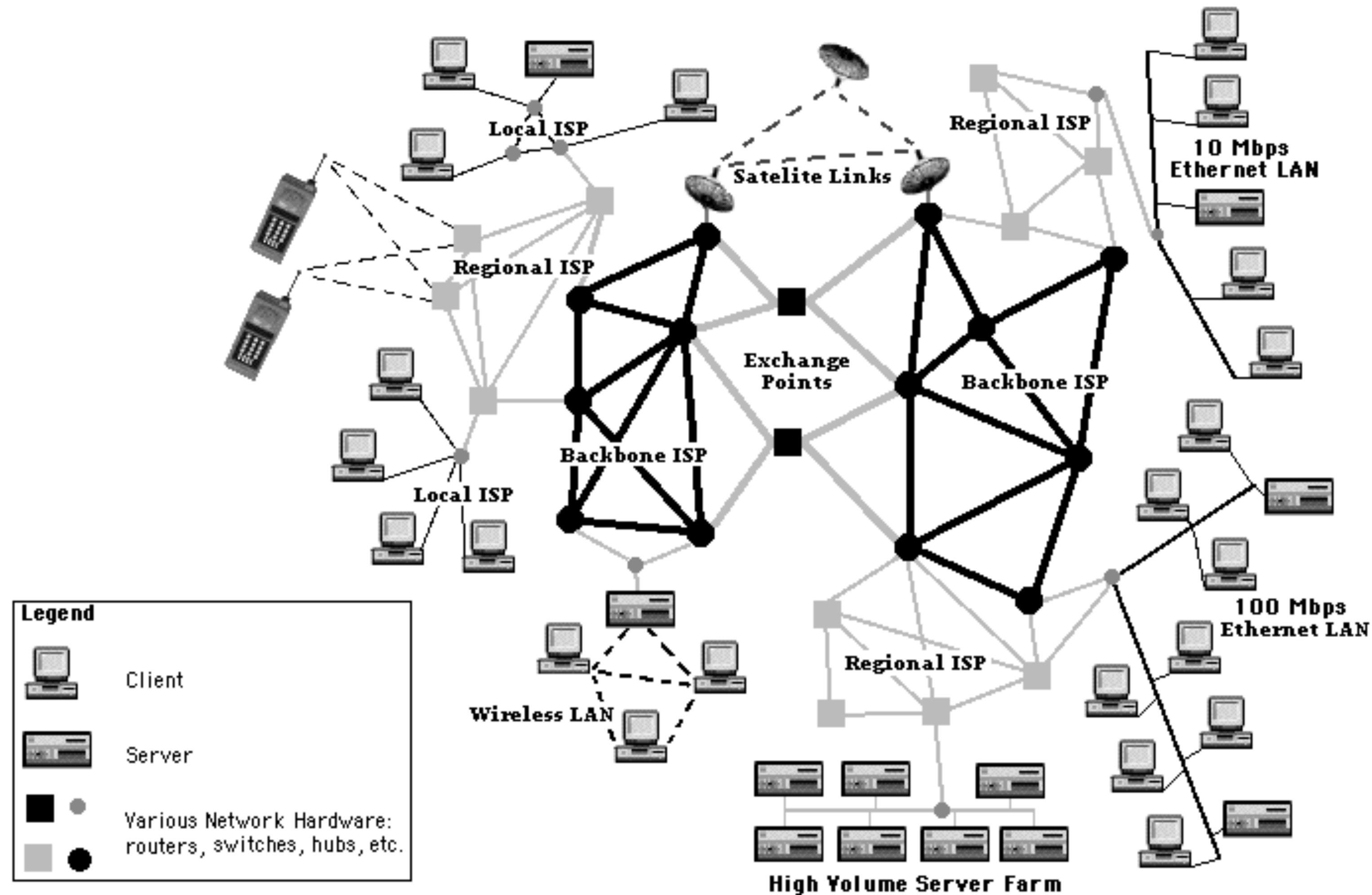


GE Washer/Dryer

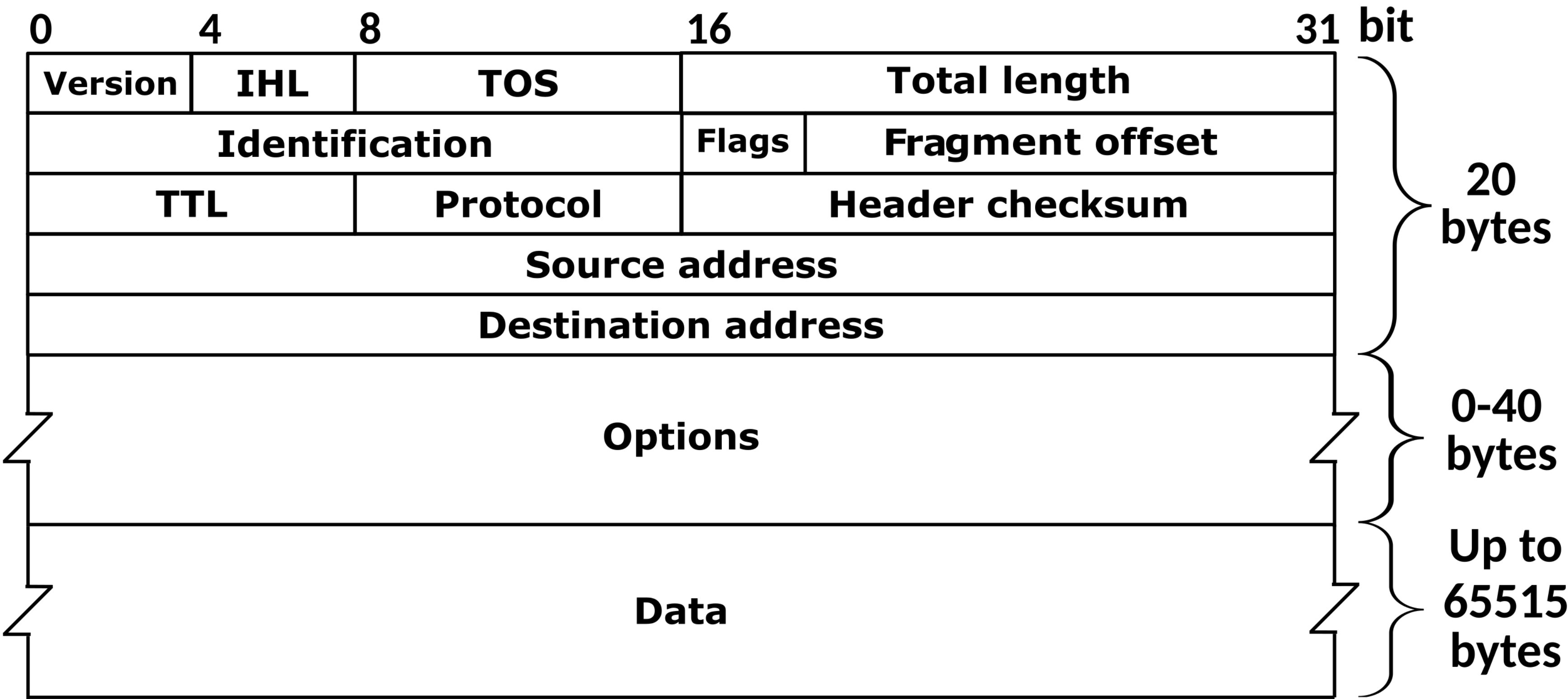


The What of Things?

The Internet is a set of networks that use the Internet Protocol (IP) to communicate.



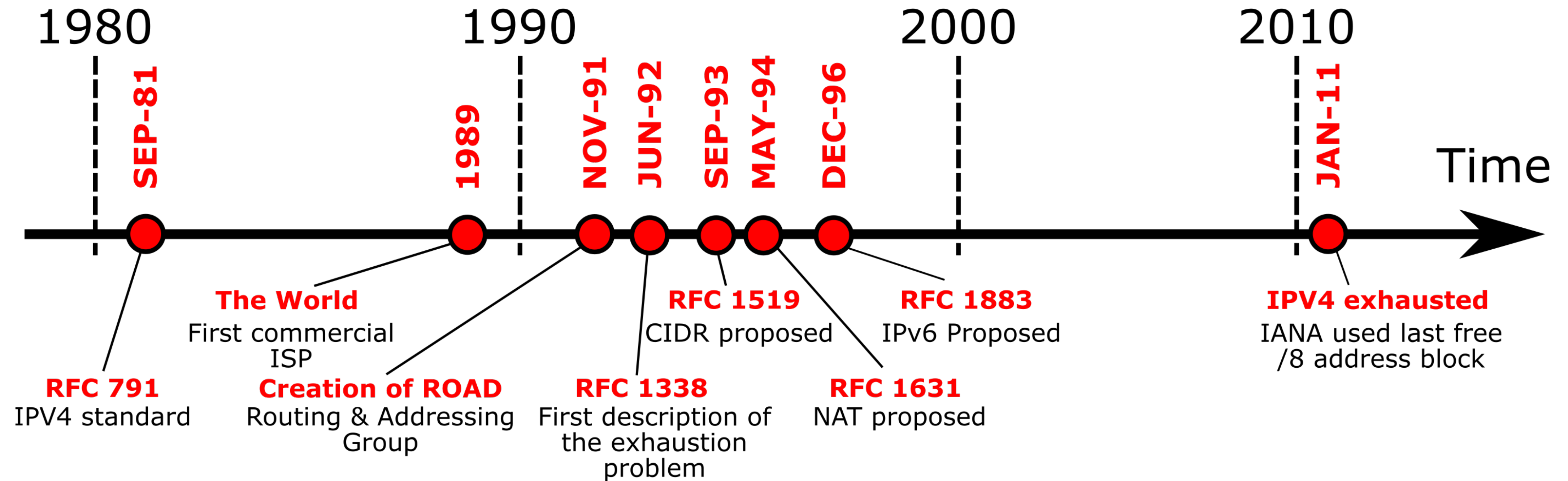
IPv4 uses 32-bit addresses



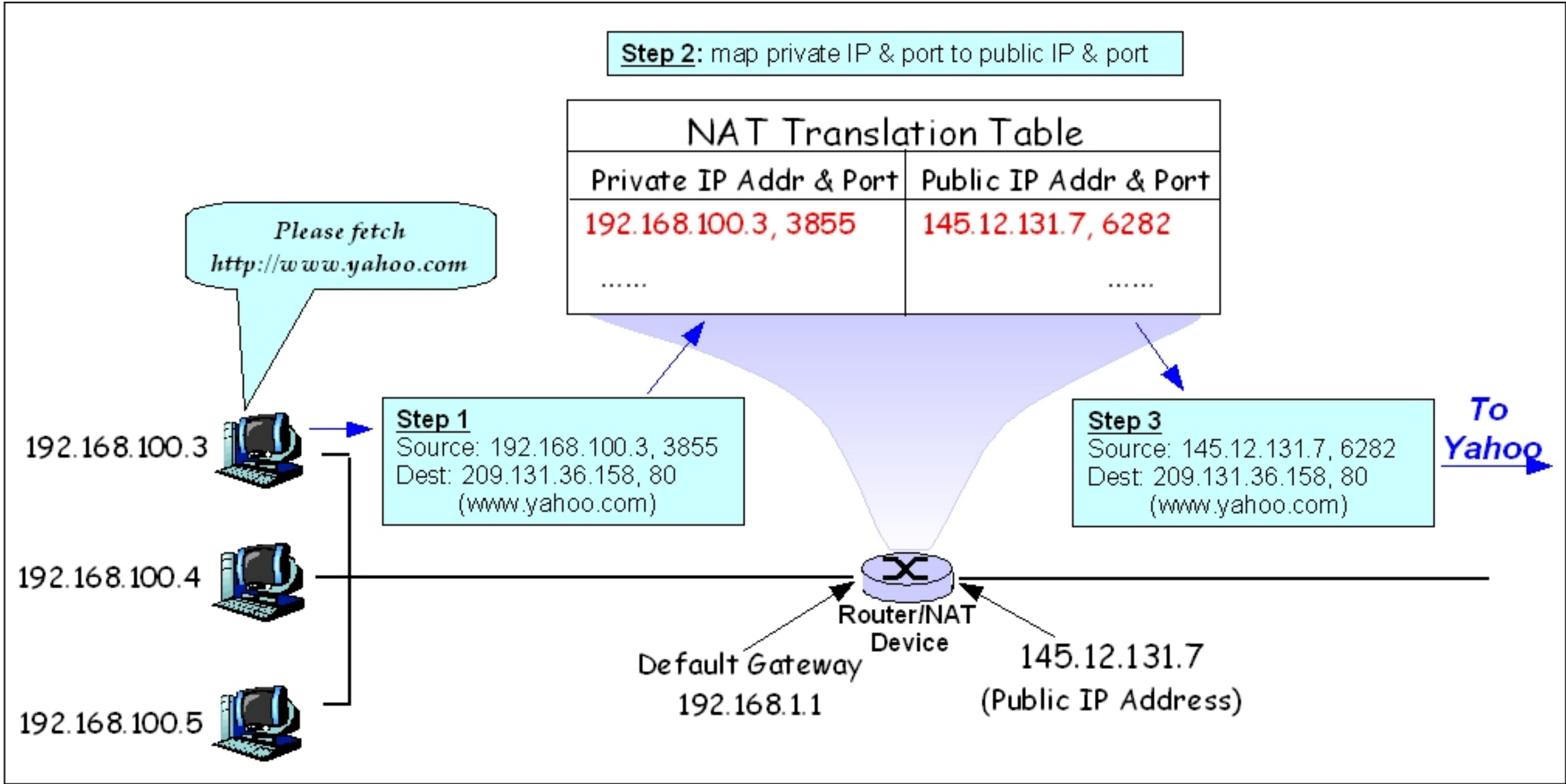
Sample addresses:

- 127.0.0.1 loopback address
- 10.0.0.1 local network gateway
- 8.8.8.8 A popular nameserver
- 23.185.0.1 dce.harvard.edu

The IPv4 address space is “exhausted.”

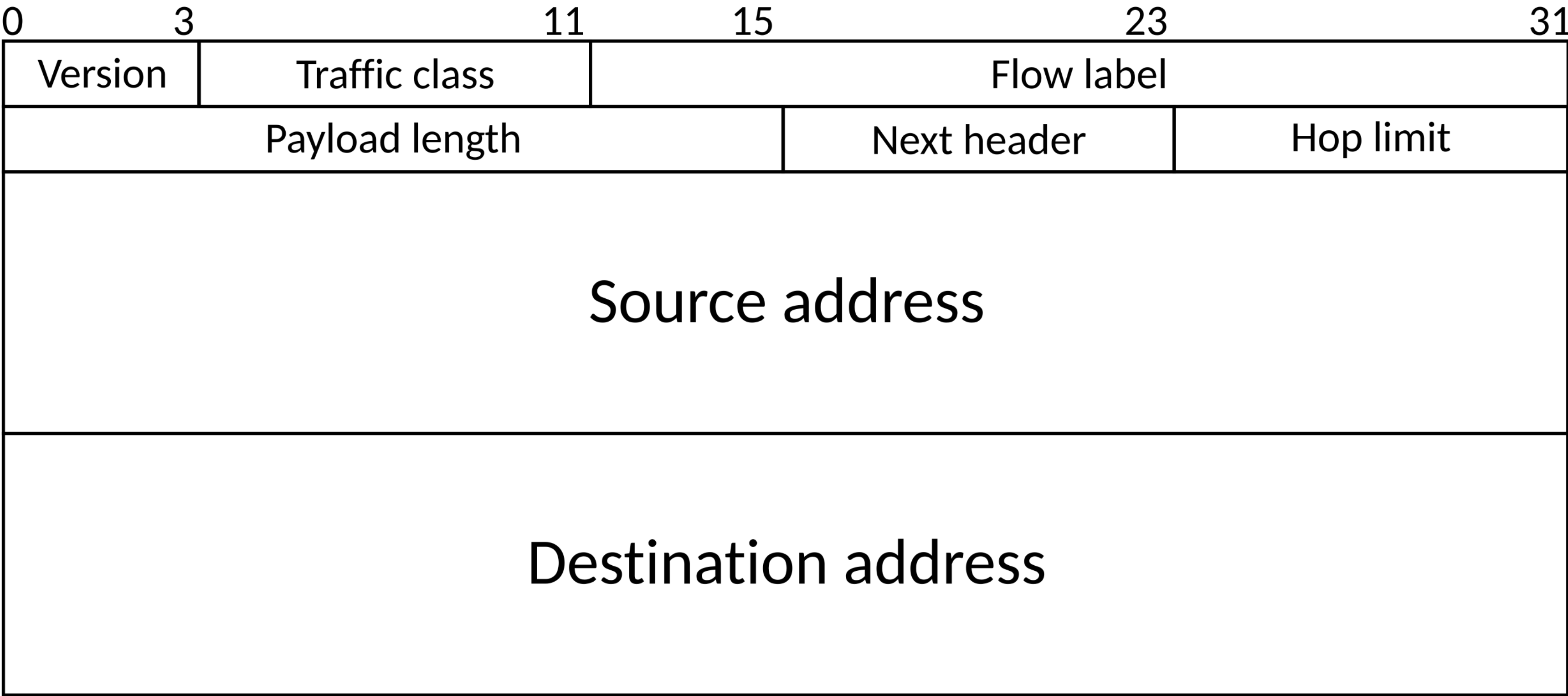


Private networks and network address translation help conserve IPv4 address space.



RFC 1918 name	IP address range	Number of addresses	Largest CIDR block (subnet mask)	Host ID size	Mask bits
24-bit block	10.0.0.0 – 10.255.255.255	16777216	10.0.0.0/8 (255.0.0.0)	24 bits	8 bits
20-bit block	172.16.0.0 – 172.31.255.255	1048576	172.16.0.0/12(255.240.0.0)	20 bits	12 bits
16-bit block	192.168.0.0 – 192.168.255.255	65536	192.168.0.0/16 (255.255.0.0)	16 bits	16 bits

IPv6 uses 128-bit addresses.



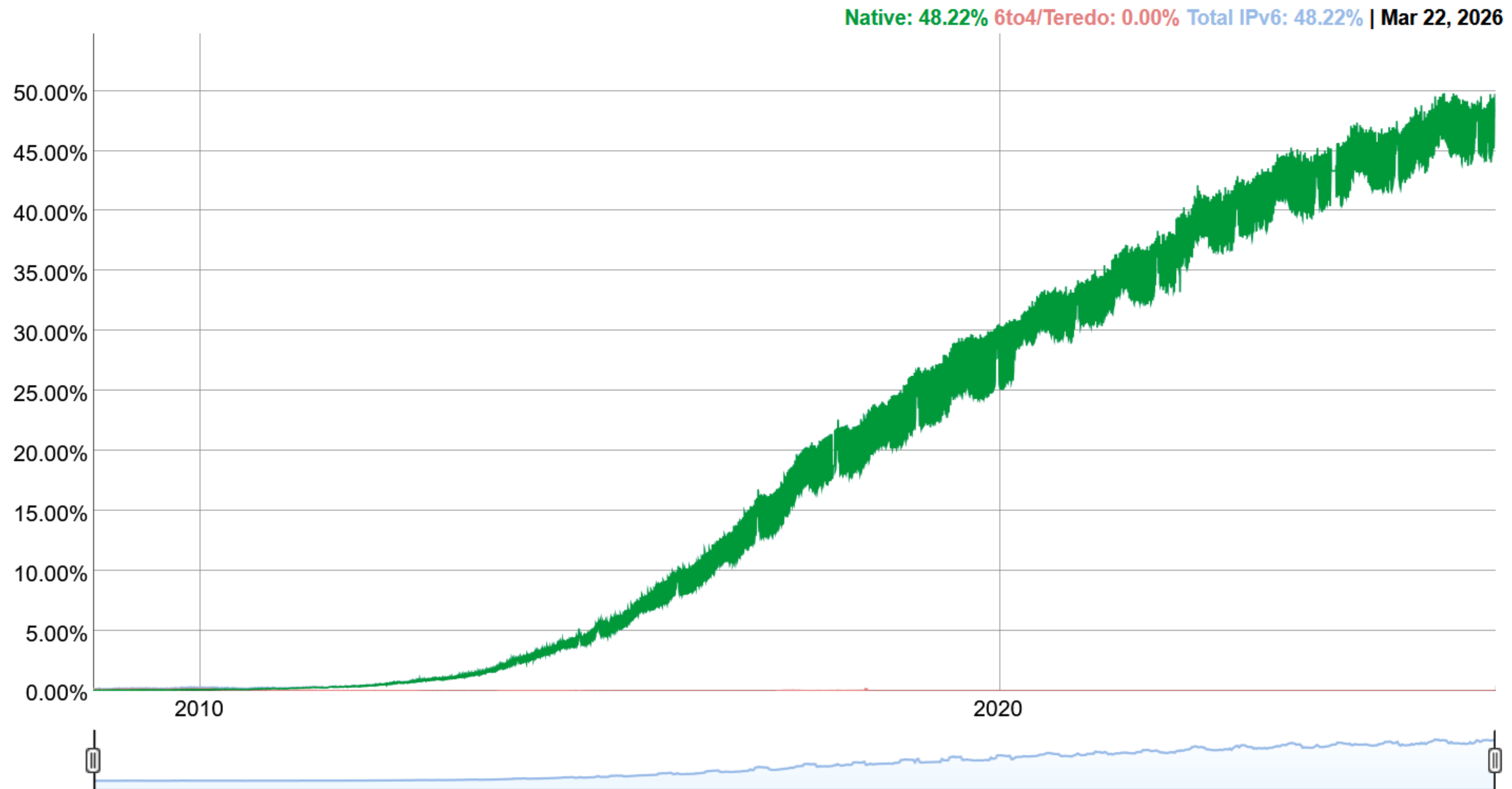
Sample addresses:

- | | |
|--------------------------|------------------|
| fe80::1 | loopback address |
| fe80::434:97ff:feef:3a1d | local IP address |
| 2620:12a:8000::1 | dce.harvard.edu |

IPv6 adoption is inching toward 50%.

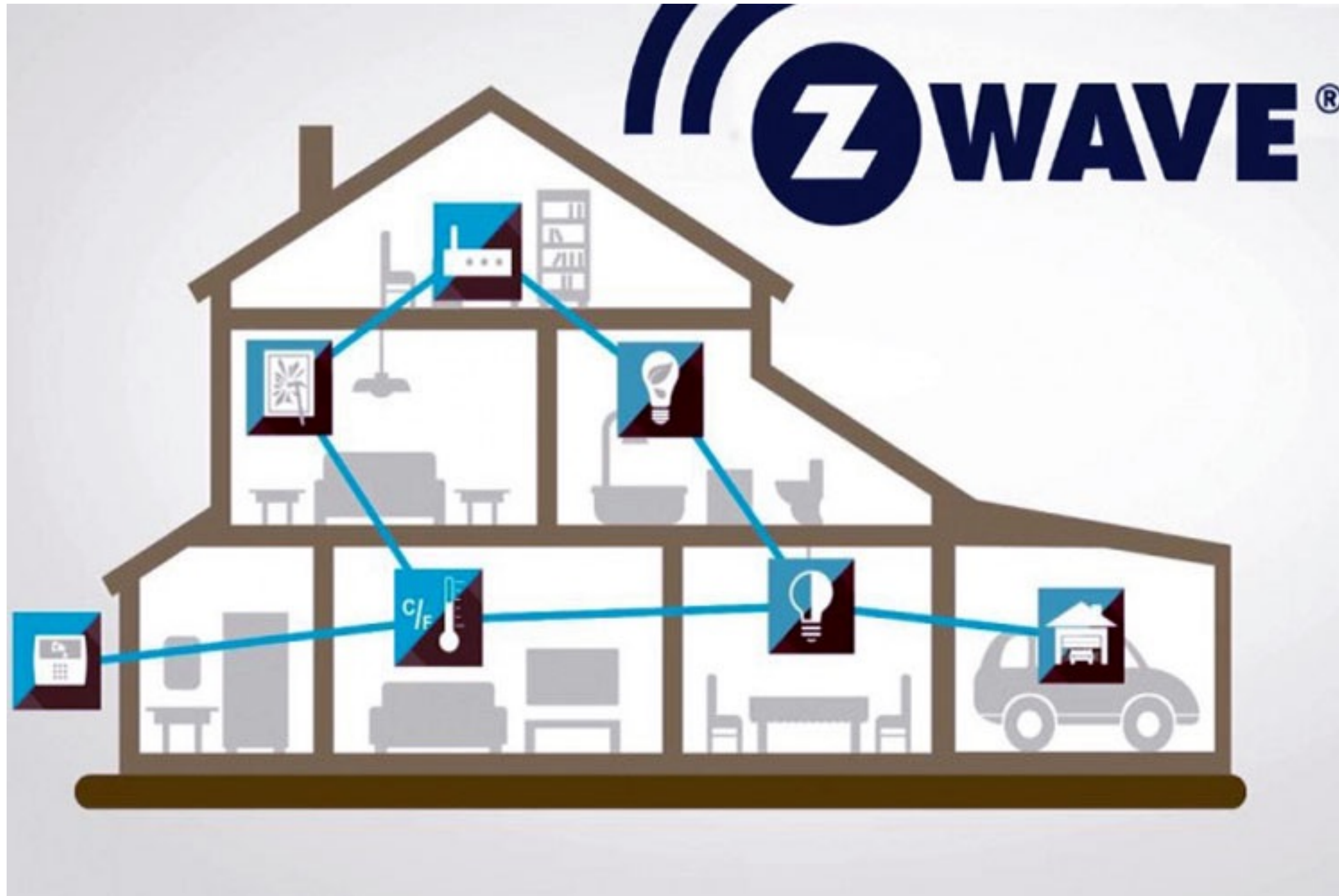
IPv6 Adoption

We are continuously measuring the availability of IPv6 connectivity among Google users. The graph shows the percentage of users that access Google over IPv6.



<https://www.google.com/intl/en/ipv6/statistics.html>

Local networks of IoT devices often use mesh networks to communicate.



<https://circuitdigest.com/article/understanding-z-wave-protocol-and-its-role-in-home-automation>

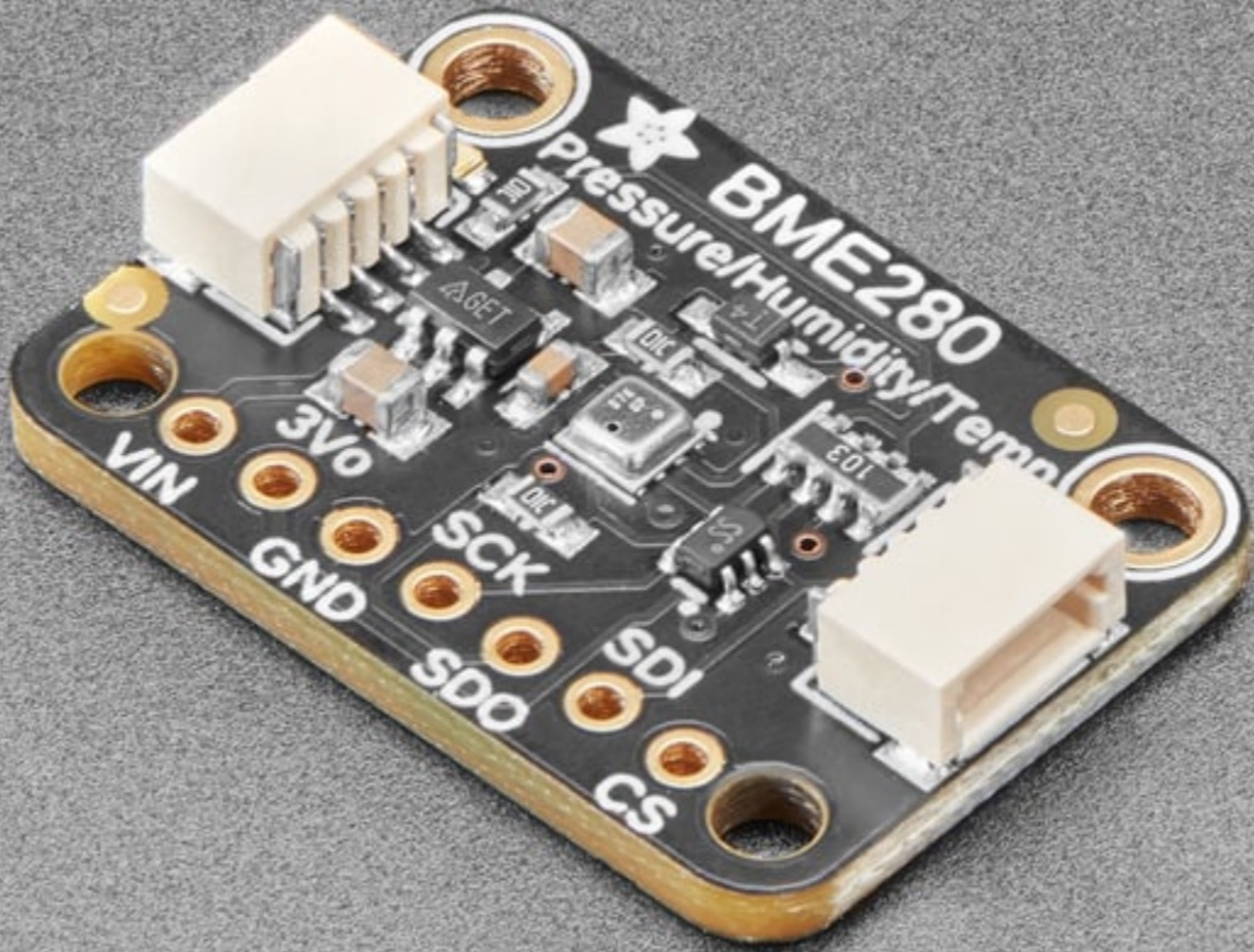
Short- and medium-distance mesh networking examples

Wi-Fi HaLow	Over 1 km	150 kb/s-86.7 Mb/s	1,2,4,8,16 MHz	Sub-1 GHz	Home security & automation, Electric Vehicle (EV) charging, video surveillance, and utility infrastructure monitoring
Bluetooth® Classic	100 m	1-3 Mbit/s	1 MHz	2.4 GHz	Home automation and consumer technologies (headphones, smartphones, laptops, etc.)
Bluetooth® LE	100 m or more	125 Kbps-2 Mbps	2 MHz	2.4 GHz	Home security & automation, asset tracking, and consumer technologies
Zigbee	10-100 m	20-250 kb/s	2 MHz	2.4 GHz (Global)	Home & building automation and smart lighting

NB-IoT	1 km (urban), 10 km (rural)	127 Kbps (downlink), 150 Kbps (uplink)	200 kHz	400, 600-900, 1400, 1500, 1700-2100 MHz	Smart metering and condition-based monitoring
LTE-M	1 km (urban), 10 km (rural)	4 Mbps (downlink), 7 Mbps (uplink)	5 MHz	700-900, 1700-2100 MHz	Asset tracking, home automation, condition-based monitoring, and smart metering
LTE Cat-1	25 to 35 km (with Line of Sight (LoS))	10 Mbps (downlink), 5 Mbps (uplink)	20 MHz	400, 700-900, 1700-1900, 2100, 2500-2600 MHz	Condition-based monitoring, telematics, Point-of-Sale (PoS) machines, and vending machines
LoRaWAN	5 km (urban), <15 km (rural)	50 Kbps	125 kHz, 250 kHz, 500 kHz	400, 500, 800, 900 MHz	Smart city, condition-based monitoring, and commercial building automation

Sensors

Sensor examples



Adafruit BME280 I2C or SPI Temperature Humidity Pressure Sensor - STEMMA QT

Product ID: 2652

\$14.95

In stock

1

Add to Cart

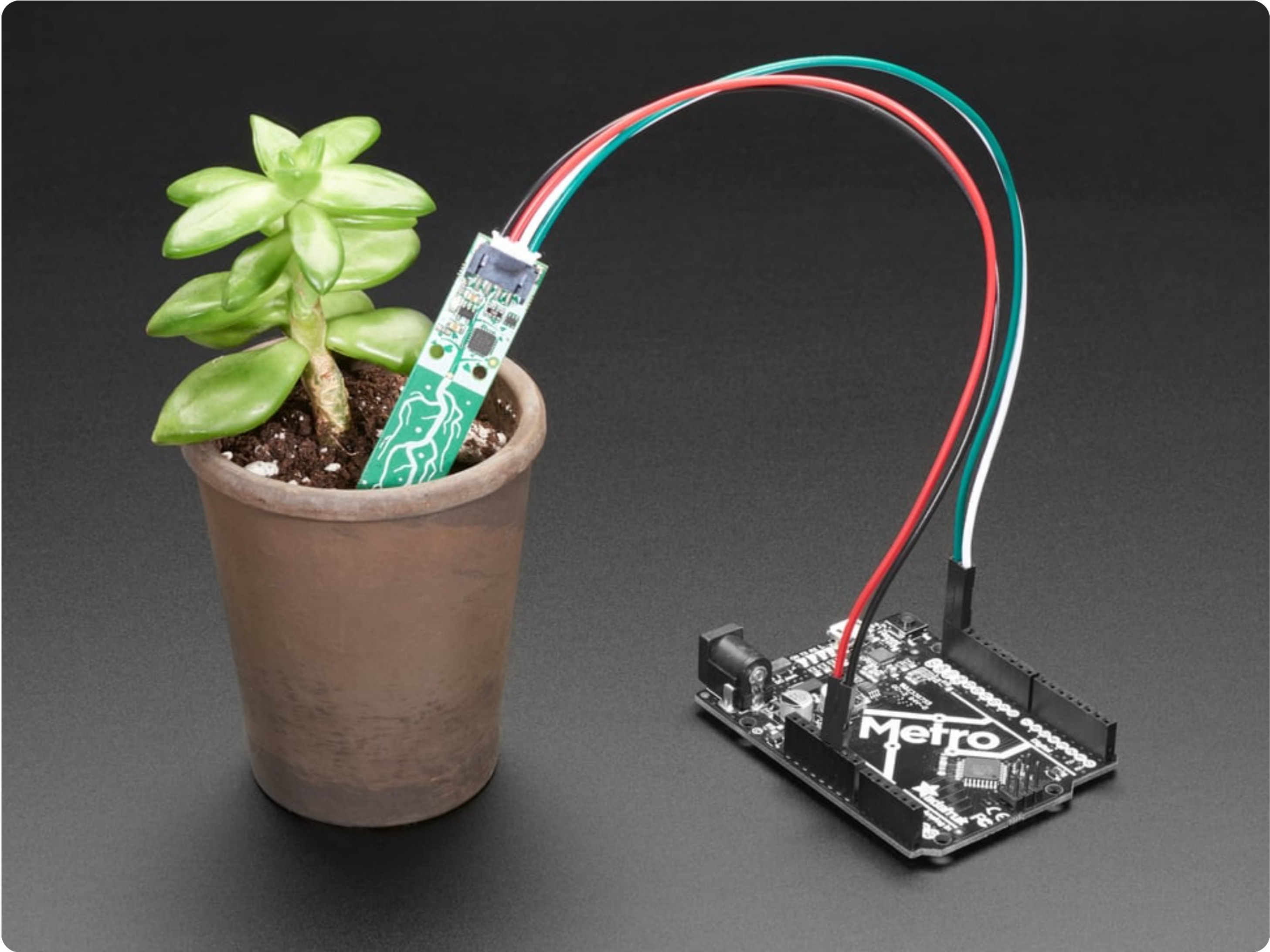
Qty	Discount
1-9	\$14.95
10-99	\$13.46
100+	\$11.96

Add to Wishlist ▾

Description

Technical Details

Sensor Examples



Adafruit STEMMA Soil Sensor - I2C Capacitive Moisture Sensor - JST PH 2mm

Product ID: 4026

\$7.50

In stock

1

Add to Cart

- ☐ Also include 1 x [JST PH 2mm 4-Pin to Female Socket Cable - I2C STEMMA Cable](#) (\$1.50)
- ☐ Also include 1 x [JST PH 2mm 4-Pin to Male Header Cable - I2C STEMMA Cable - 200mm](#) (\$1.50)
- ☐ Also include 1 x [STEMMA Cable - 4 Pin JST-PH 2mm Cable–Female/Female](#) (\$0.75)

Qty	Discount
1-9	\$7.50
10-99	\$6.75
100+	\$6.00

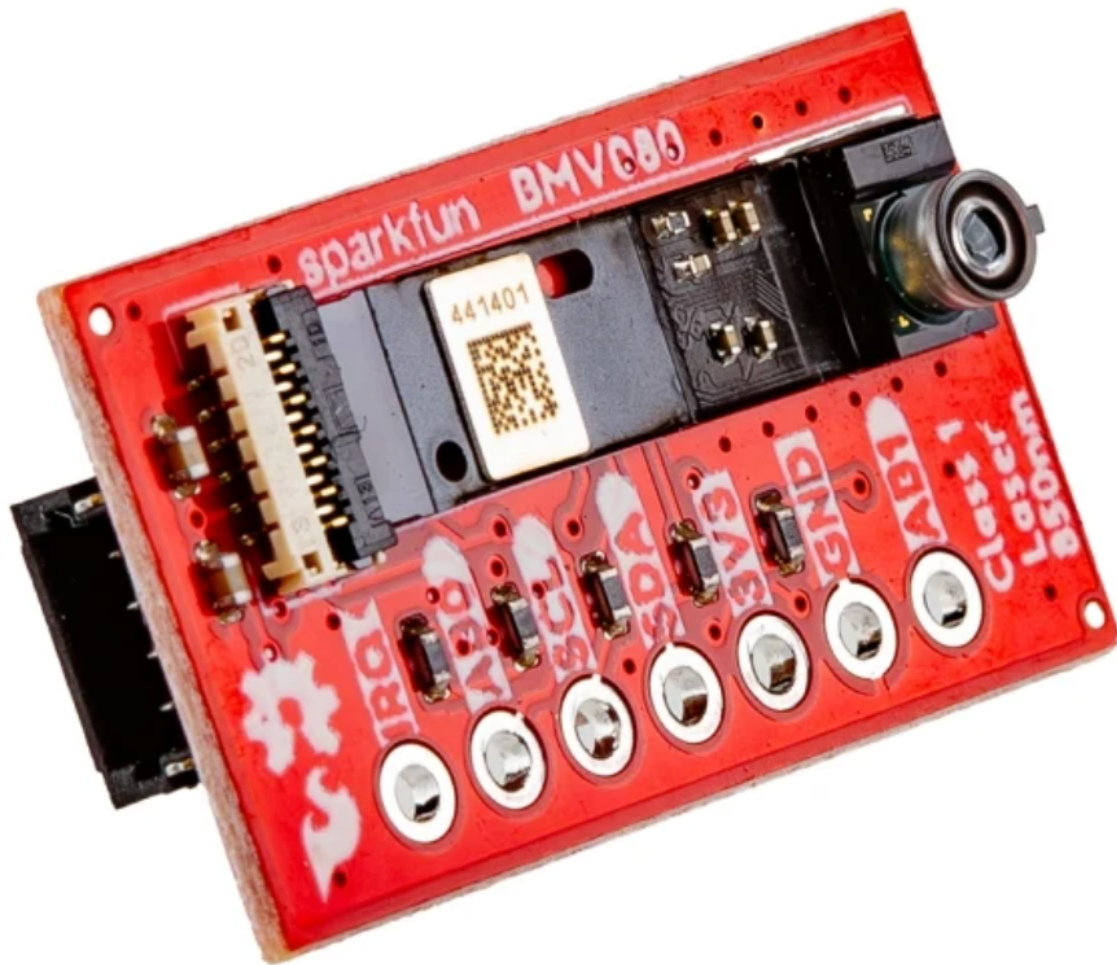
Add to Wishlist ▾

Description

Technical Details

Sensor Examples

Share: [f](#) [t](#) [in](#)



SparkFun Air Quality PM1/PM2.5/PM10 Sensor - BMV080 (Qwiic)

★ ★ ★ ★ ★ No reviews

SKU: SEN-26554

Measure air quality with unprecedented precision and size using the SparkFun Qwiic BMV080 sensor, the world's smallest PM1/PM2.5/PM10 detector.

\$64.95

-

1

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- [SCHEMATIC](#)
- [DATASHEET - BMV080](#)

Sensor Examples

[HOME](#) / [SENSORS](#) / [RFID](#) / [RFID READERS](#)

Share: [f](#) [t](#) [in](#)



SparkFun RFID Qwiic Reader

★ ★ ★ ★ ★ No reviews

SKU: SEN-15191

The SparkFun RFID Qwiic Reader is a simple I2C based RFID breakout board for the ID-3LA, ID-12LA, and ID-20LA readers.

\$23.50

-1+

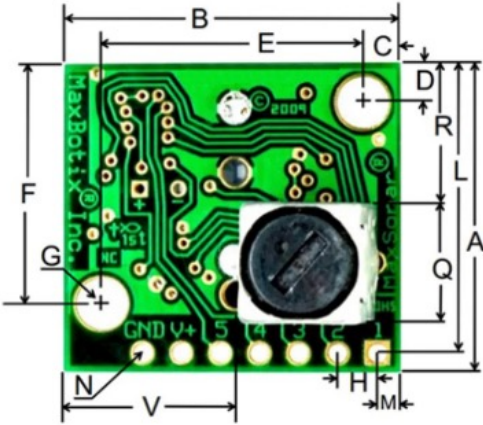
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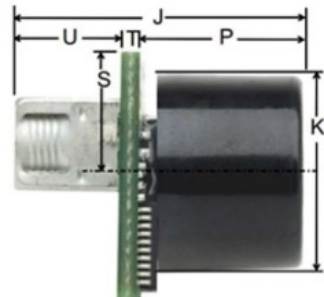
Sensor Examples



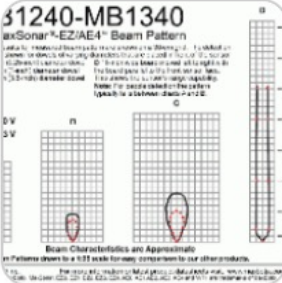


A	0.785"	19.9mm	L	0.735"	18.7mm
B	0.870"	22.1mm	M	0.065"	1.7mm
C	0.100"	2.54mm	N	0.038"	1.0mm _{as}
D	0.100"	2.54mm	P	0.537"	13.64mm
E	0.670"	17.0mm	Q	0.304"	7.72mm
F	0.610"	15.5mm	R	0.351"	8.92mm
G	0.124"	3.1mm _{as}	S	0.413"	10.5mm
H	0.100"	2.54mm	T	0.079"	2.0mm
J	0.989"	25.1mm	U	0.368"	9.36mm
K	0.645"	16.4mm	V	0.492"	12.5mm
Weight, 5.9 grams					

Value Are Nominal



Board Color May Vary



MB1240 XL-MaxSonar-EZ4

 [MB1240 Datasheet](#)

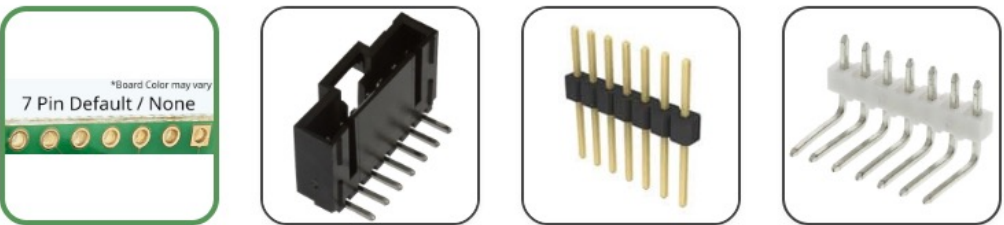
Ranges from 20cm to 765cm with a 10Hz read rate. Narrowest detection field. Highest noise tolerance.

-  Ultra-Accurate Distance Measurement
-  Seamless Integration, Instant Results
-  Proven Performance, Trusted Worldwide

MSRP ~~\$39.95 USD~~ for default configuration

\$32.65  [Shipping calculated at checkout.](#)

Connection Details: 7 Pin Default / None



Related Products Add On(s) None

- None
- EZ Mounting Hardware (MB7940-000)

Quantity

−

1

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Request a Quote

TALK TO AN EXPERT



Hi there! 🙌 How can we assist you?

This chat is not typically monitored live, but please leave your message and email, and someone from our team will get back to you as soon as possible.

Sensor Examples

[HOME](#) / [SENSORS](#) / [INFRARED](#)

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SparkFun Proximity Sensor Breakout - 20cm, VCNL4040 (Qwiic)

★★★★★ 1 review ▾

SKU: SEN-15177

The SparkFun Proximity Sensor Breakout is a simple IR presence and ambient light sensor utilizing the VCNL4040.

\$8.50

-

1

+

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♡ ADD TO WISH LIST

⇄ COMPARE



ZX Distance and Gesture Sensor

★★★★☆ 3 reviews ▾

SKU: SEN-13162

\$28.50

-

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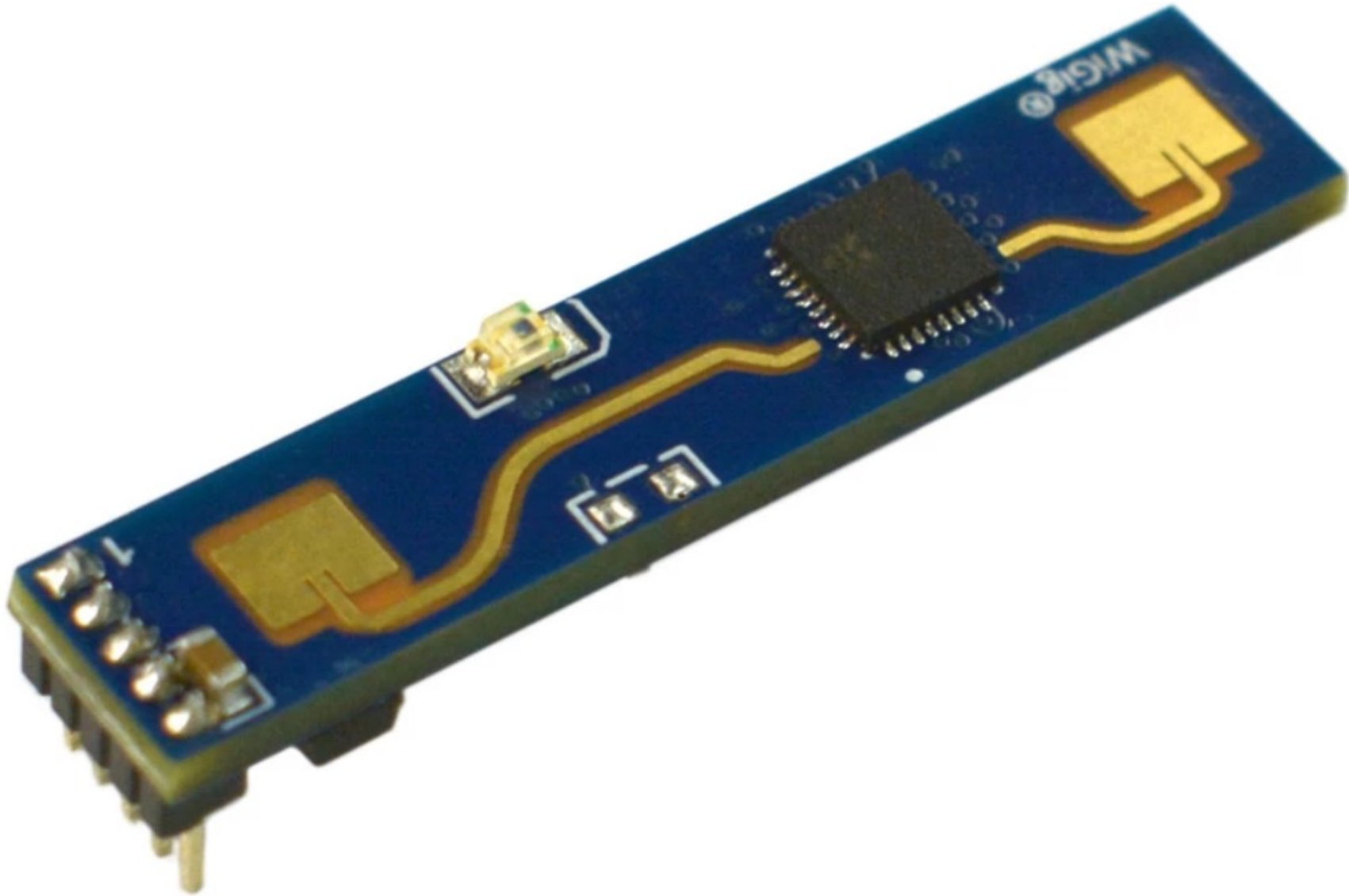
ADD TO WISH LIST



COMPARE

HELPFUL DOCUMENTATION

Sensor Examples



mmWave - 24GHz Human Presence Sensing Module (6 Meters)

\$9.90

SKU: SEN0557

-

1

+

Volume Discount ⓘ

 Purchase this product and earn 99 reward points, which are tied to VIP membership program. [Learn More >](#)

Don't Miss Top Accessories



mmWave - C4001 24GHz Human Presence Detection Sensor (25 Meters, UART)

\$13.90

-

1

+

[Details ⓘ](#)



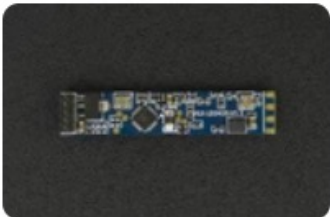
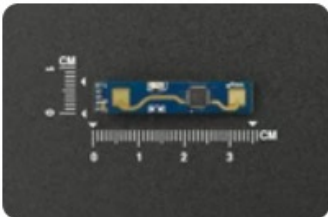
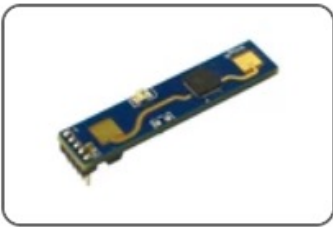
5.8GHz Microwave Radar Module

\$11.00

-

1

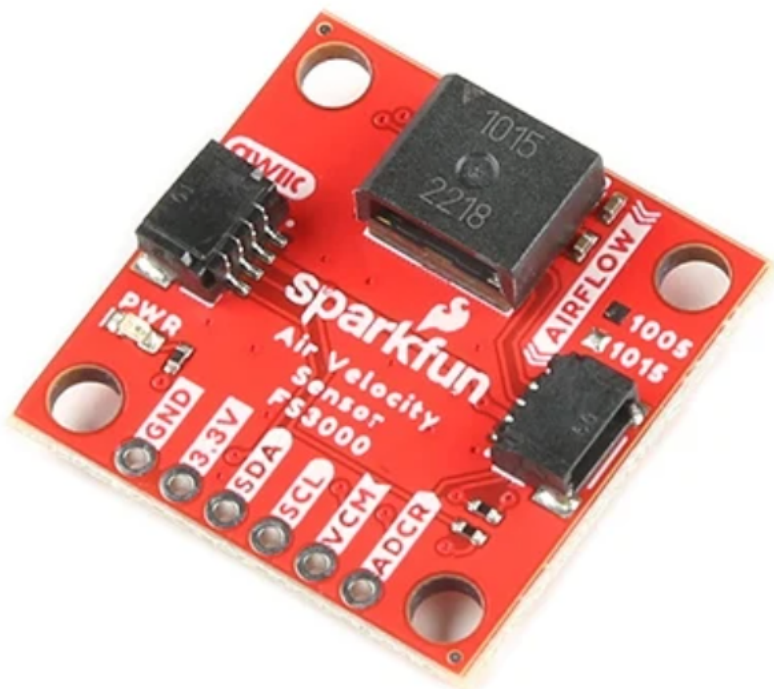
+



Sensor Examples

[HOME](#) / [SENSORS](#) / [MISC. SENSORS](#)

Share: [f](#) [t](#) [in](#)



SparkFun Air Velocity Sensor Breakout - FS3000-1015 (Qwiic)

★★★★★ 2 reviews ▾

SKU: SEN-18768

The SparkFun FS3000-1015 Qwiic Air Velocity Sensor Breakout can help you accurately determine the speed and consistency of air moving around you.

\$79.50

-

1

+

Add to Cart

IN STOCK [STOCK/DISCOUNTS](#)

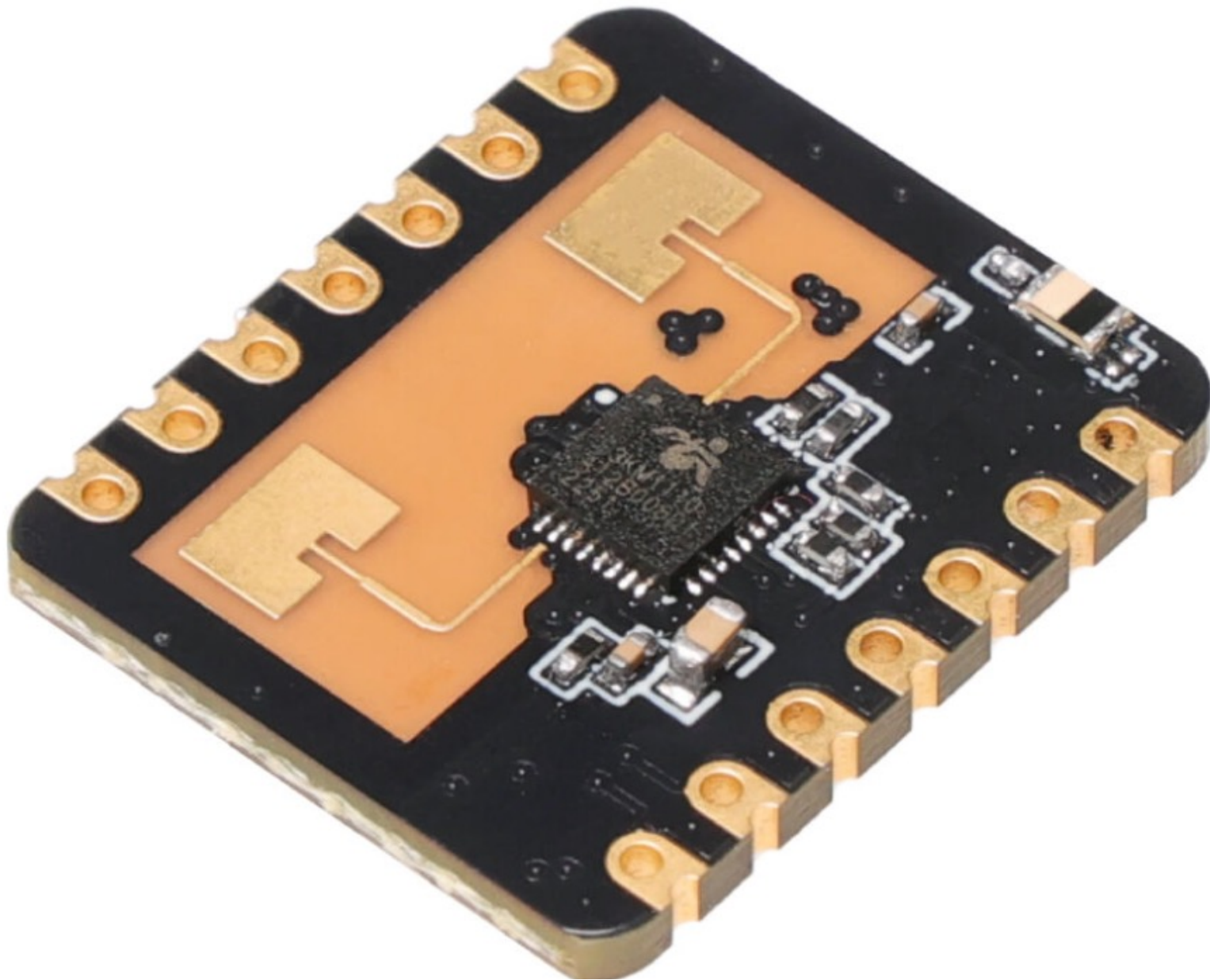
ADD TO WISH LIST COMPARE

HELPFUL DOCUMENTATION

- [HOOKUP GUIDE](#)
- [SCHEMATIC](#)
- [DATASHEET \(FS3000-1015\)](#)

Sensor Examples

Home / The Modules / Smart Sensing / Room Sensing / 24Ghz mmwave Human Static Presence Sensor for Sseed Studio XIAO



24Ghz mmwave Human Static Presence Sensor for Sseed Studio XIAO

SKU 101010001

★★★★★ [8 Reviews](#)

24GHz mmWave Sensor for XIAO - Human Static Presence is a expansion board for Sseed Studio XIAO series. It is an antenna-integrated, high-sensitivity mmwave radar sensor that is based on the FMCW principle. Combined with radar signal processing and accurate human body sensing algorithms, it can identify human bodies in motion and stationary states.

USD **\$4.49**

10+: \$3.99

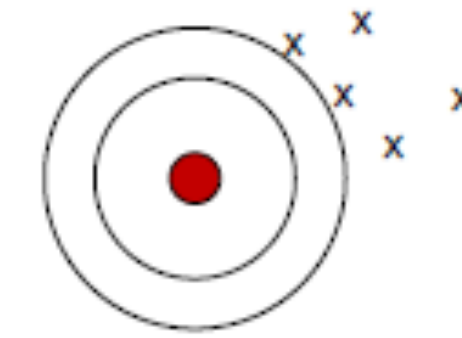
1+ in stock

PowerBread

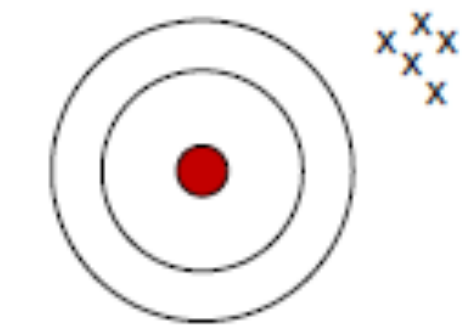
CAN Bus Breakout Board

Potentially relevant sensor attributes

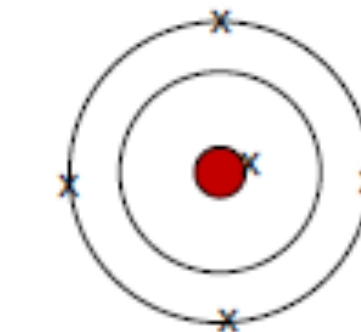
- Accuracy (and offset or drift)
- Range of detection (and linearity)
- Precision (and sensitivity)
- Speed to obtain a sample
- Sensitivity to electrical or thermal noise
- Power consumption
- Quantity of data generated



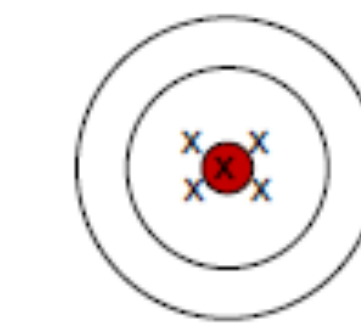
Imprecise and Inaccurate



Precise but Inaccurate



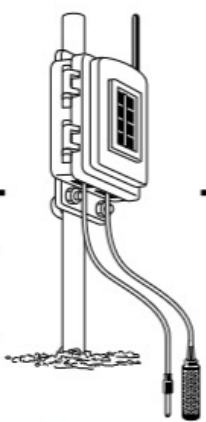
Accurate but Imprecise



Precise and Accurate

Spec Sheets define the operating characteristics of a sensor.

Wireless Soil Moisture/Temperature Station



6361

VANTAGE PRO

The Wireless Soil Moisture/Temperature Station for Vantage Pro™ monitors up to four temperature-compensated soil moisture sensors anywhere within transmission range of your wireless Vantage Pro console. The station communicates directly to your Wireless Vantage Pro console/receiver over any one of eight user-selectable DavisTalk™ ID codes, and has a transmitting range of between 100' to 400' (30 to 122 m) depending upon the environment. The station comes standard with one soil moisture sensor and one temperature probe, is solar powered, and includes a battery backup.

The WATERMARK soil moisture sensor is an indirect, calibrated method of measuring soil water. It is an electrical resistance type sensor. The Vantage Pro weather station converts the electrical resistance reading from the sensor into a calibrated reading of centibars of soil water suction. The Multi-Purpose Temperature Probe is a precision platinum wire thermistor that produces a resistance change proportional to temperature. The temperature probe is used by the station to provide temperature compensation for the associated soil moisture reading.

The WATERMARK soil moisture sensor is a product of the Irrometer Company, Inc.

Specifications

General

Operating Temperature	-40° to +150°F (-40° to +65°C)
Non-operating Temperature	-50° to +158°F (-45° to +70°C)
Current Draw	0.07 mA (average), 10 mA (peak) at 4 to 6 VDC power
Battery	CR123A 3-Volt Lithium cell
Battery Life	up to 1 year
Solar Panel	0.5 Watts
Housing Material	UV-resistant ABS plastic
Dimensions	6.25" x 2.25" x 7.875" (158.75 mm x 57.15 mm x 200 mm)
Weight	1.08 lb. (.49 kg) (with battery, without sensors)

Watermark Soil Moisture Sensor (6440)

Sensor Type	Electrical resistance
Standard Cable	15' (4.6 m) Watermark standard two-wire, stripped and tinned
Maximum Cable Length	18 AWG: 1000' (UF wire recommended)

Multi-Purpose Temperature Probe (6470)

Sensor Type	Platinum wire thermistor
Standard Cable	15' (4.6m) 22 AWG direct burial cable, stripped and tinned
Maximum Cable Length	24 AWG: 800' (244 m), 22 AWG: 1200' (365 m)

Wireless Communications

Transmit/Receive Frequency	US Models: 916.5 MHz, Overseas Models: 868.35 MHz
ID Codes Available	8
Output Power	916.5 MHz: FCC-certified low power, less than 1 mW, no license required 868.35 MHz: CE-certified, less than 10 mW, no license required
Range	
Line of Sight	up to 400' (122 m)
Through Walls	up to 100' to 200' (30 to 60 m)

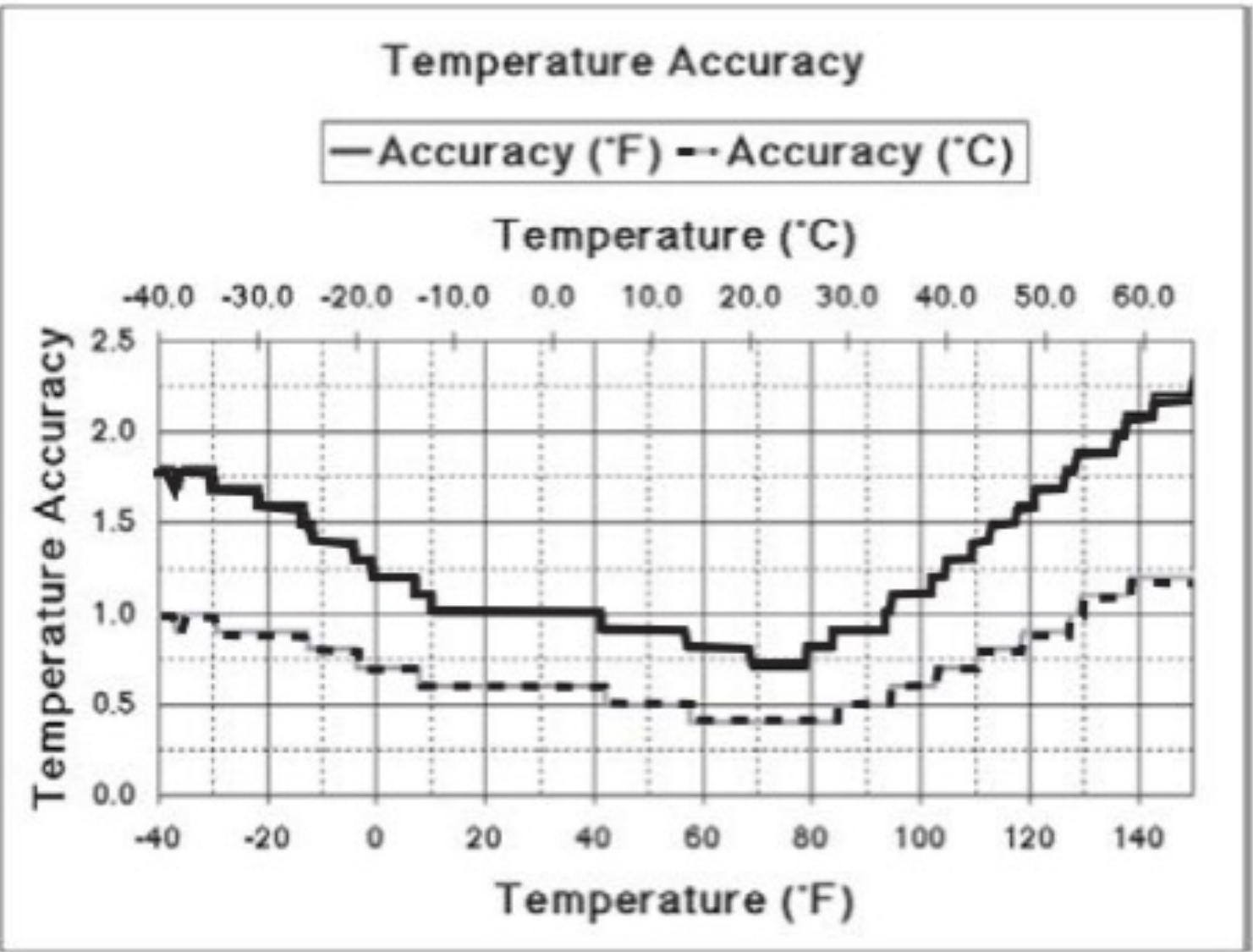
Sensor Specs

Soil Moisture (Watermark Soil Moisture Sensor)	
Resolution	1 cb
Range	0 to 200 cb
Update Interval	62.5 to 75 seconds
Current Data	Instant Reading; Daily and Monthly High and Low
Historical Data	Hourly Readings; Daily and Monthly Highs and Lows
Alarms	High and Low Thresholds from Instant Reading
Temperature	
Resolution and Units	1°F or 1°C (user-selectable)
Range	-40° to +150°F (-40° to +65° C)
Sensor Accuracy	±1°F (±0.5°C) under 110°F (43°C), ±2°F (±1°C) over 110°F (43°C) (See Chart)
Update Interval	62.5 to 75 seconds
Data	Instant Reading (user adjustable)
Alarms	High and Low Thresholds from Instant Reading

2, Wireless Soil Moisture/Temperature Station

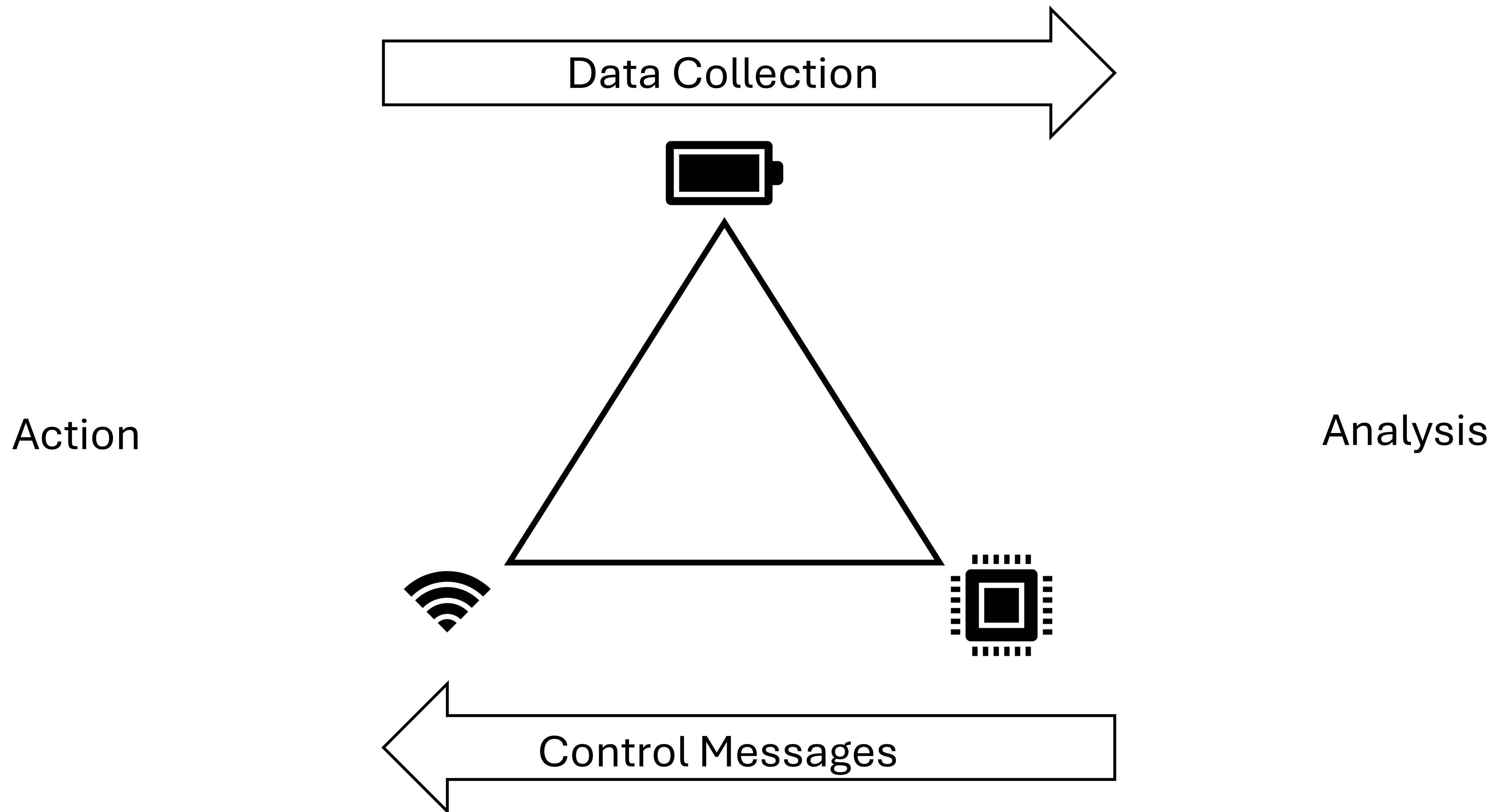
VANTAGE PRO

Temperature Accuracy Chart



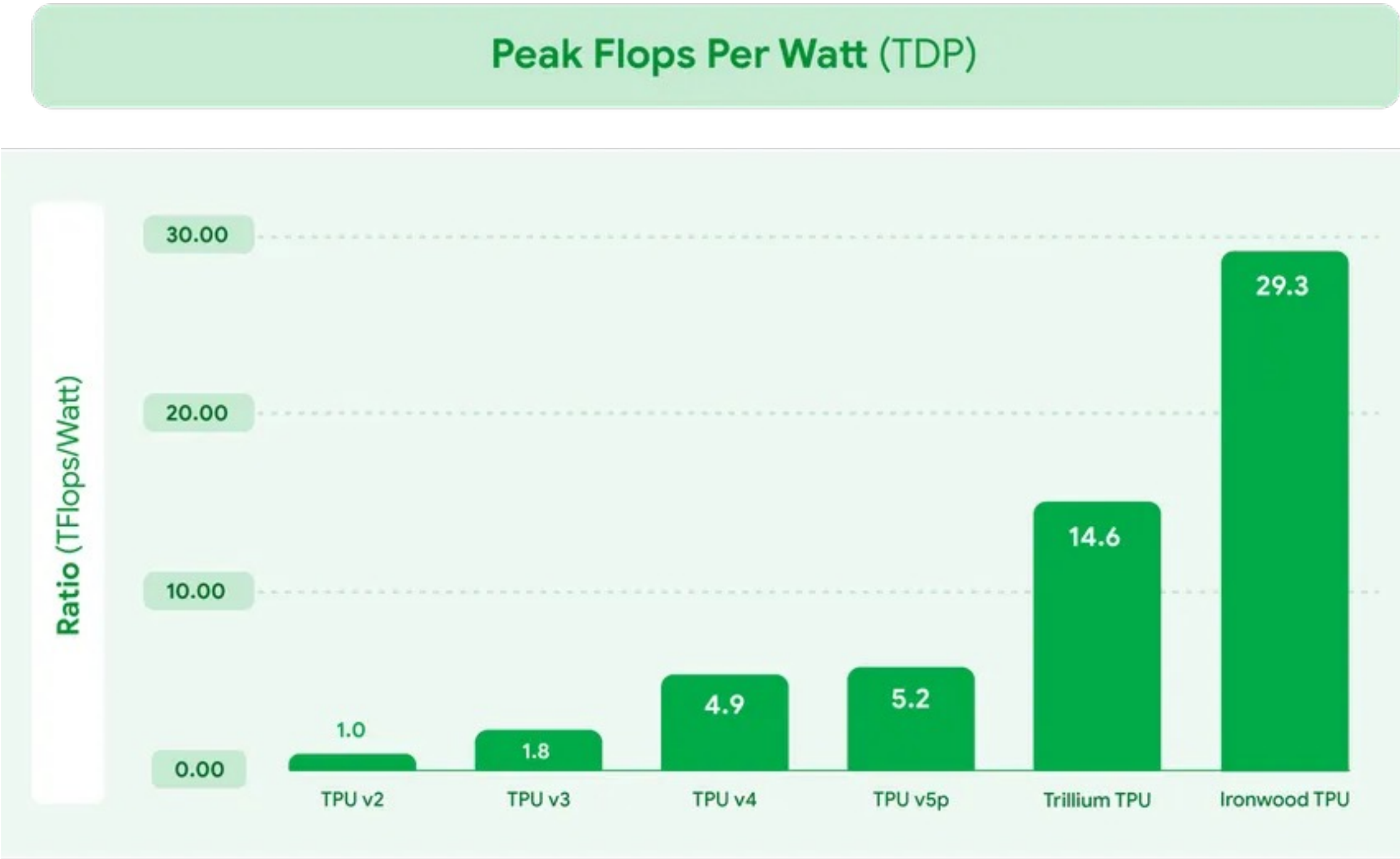
AI + IoT Architecture

In designing IoT systems, you have a budget of processing, communication, and battery.



AI chips still consume a lot of power.

			
	TPU v4	TPU v5p	Ironwood
	2022	2023	2025
Pod Size (chips)	4096	8960	9216
HBM Bandwidth/ Capacity	32 GB @ 1.2 TBps HBM	95 GB @ 2.8 TBps HBM	192 GB @ 7.4 TBps HBM
Peak Flops per chip	275 TFLOPS	459 TFLOPS	4614 TFLOPS



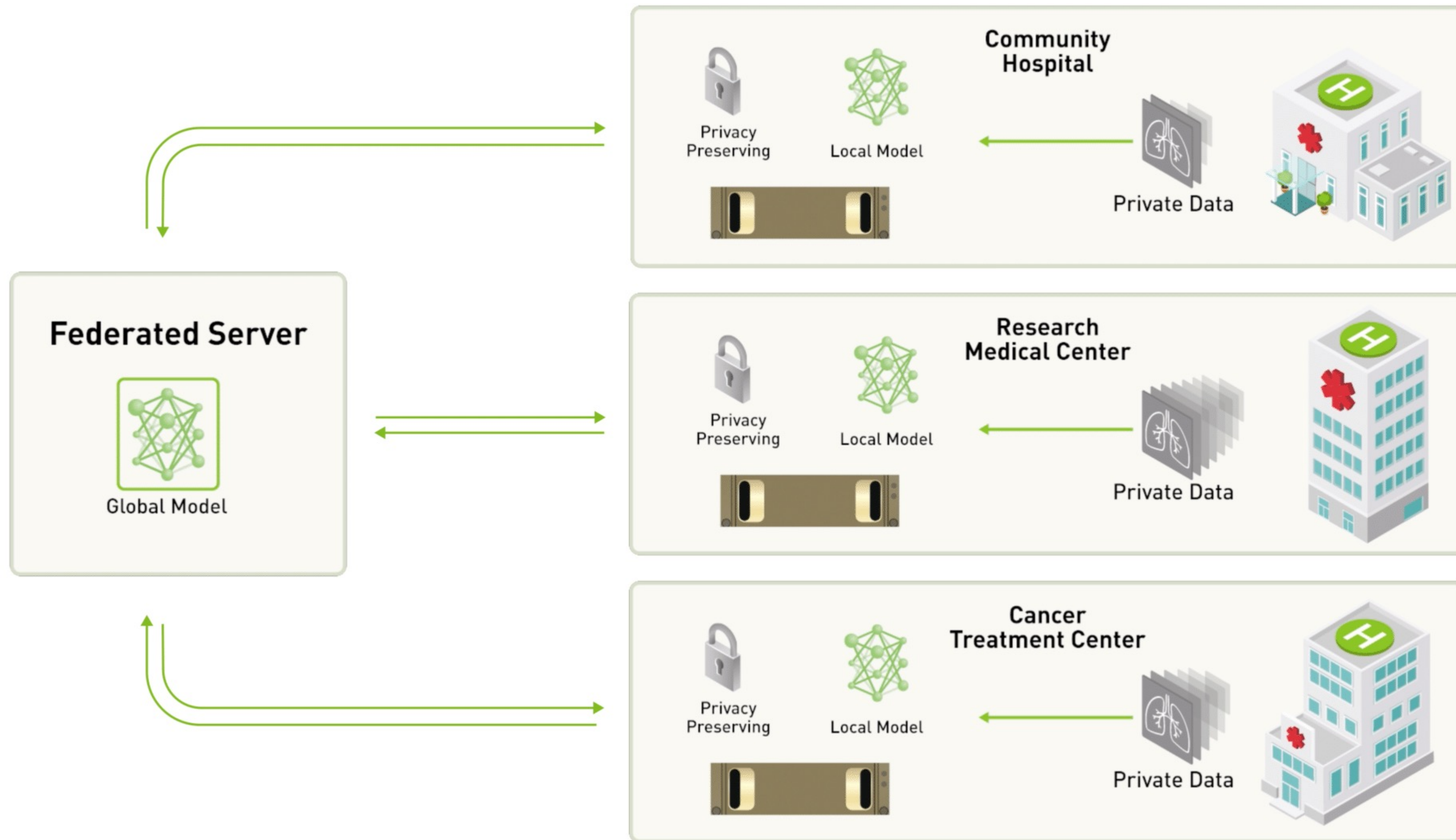
Most batteries couldn't support that chip for even an hour.

Battery Type	Typical Voltage (V)	Typical Capacity (mAh)	Energy (Wh)
AA (Alkaline)	1.5	2,500	3.75
AA (NiMH Rechargeable)	1.2	2,000	2.4
AAA (Alkaline)	1.5	1,200	1.8
9V (Alkaline)	9	500	4.5
18650 Li-ion	3.7	3,000	11.1
9V Li-ion Rechargeable	7.4	600	4.4
CR2032 (Coin Cell)	3	225	0.675
D Cell (Alkaline)	1.5	12,000	18
C Cell (Alkaline)	1.5	8,000	12
Car Battery (Lead-Acid)	12	50,000–100,000	600–1,200
Laptop Battery (Li-ion)	11.1	4,400	~49
Smartphone Battery	3.7	3,000	~11.1

Wireless communication uses power, too!

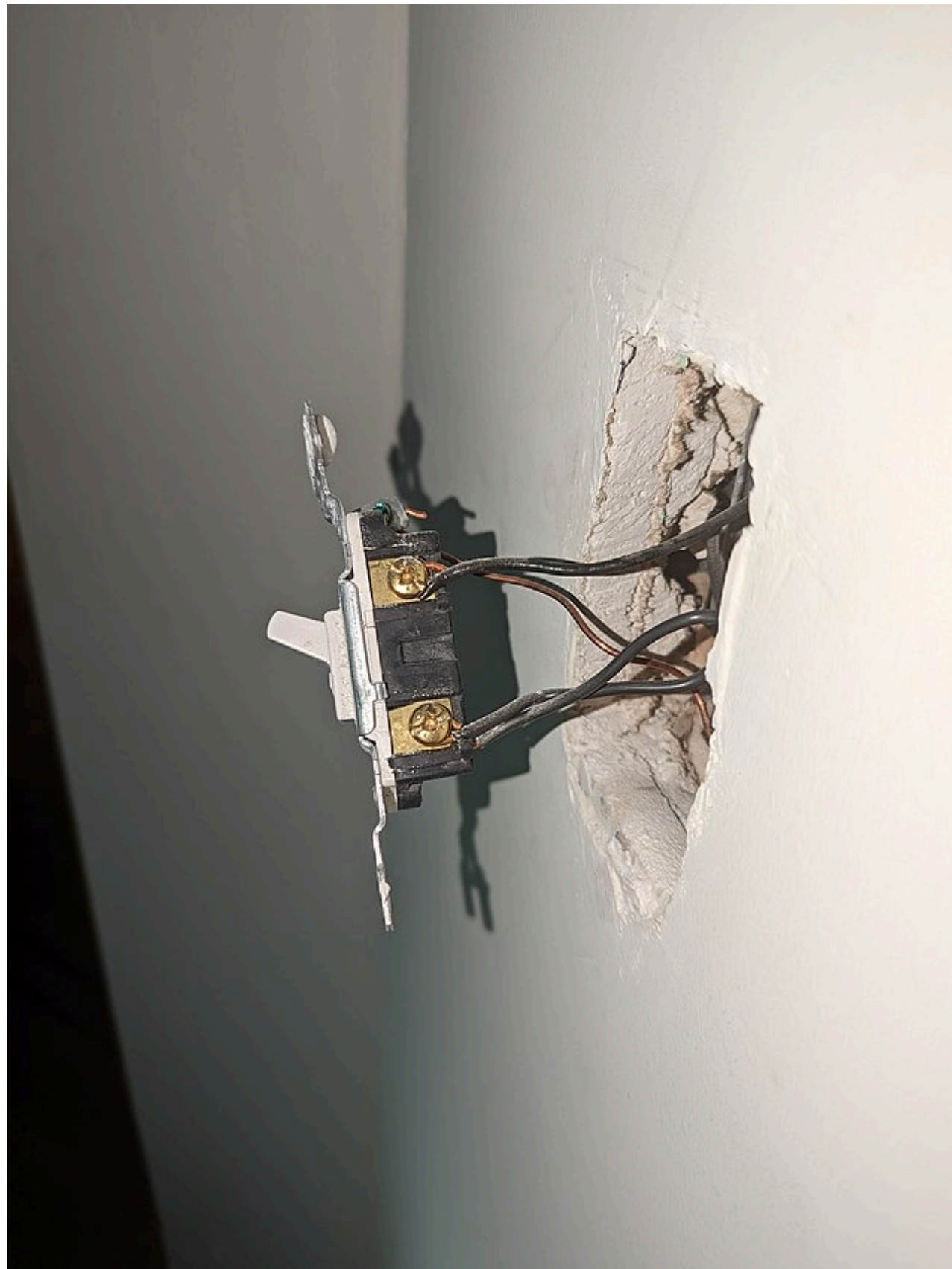
	Bluetooth LE	Nike+	ZigBee	WIFI
Power (mW)	0.147	0.675	35.7	210
Bits/sec	960	272	192	40M
Energy/bit (nJ)	153	2480	186,000	5.25

“Federated learning” lets edge devices update models locally.



IoT complicates addressing and configuration.

How it started...



How it's going

<TL/DR> What's the simplest way to set up the interaction between a light switch and lights?

Hi there!

I used to run all my light switches and bulbs through Deconz, which let me just say "Switch X controls light group Y" and I would instantly have the switch turn the light on, off, raise and lower brightness.

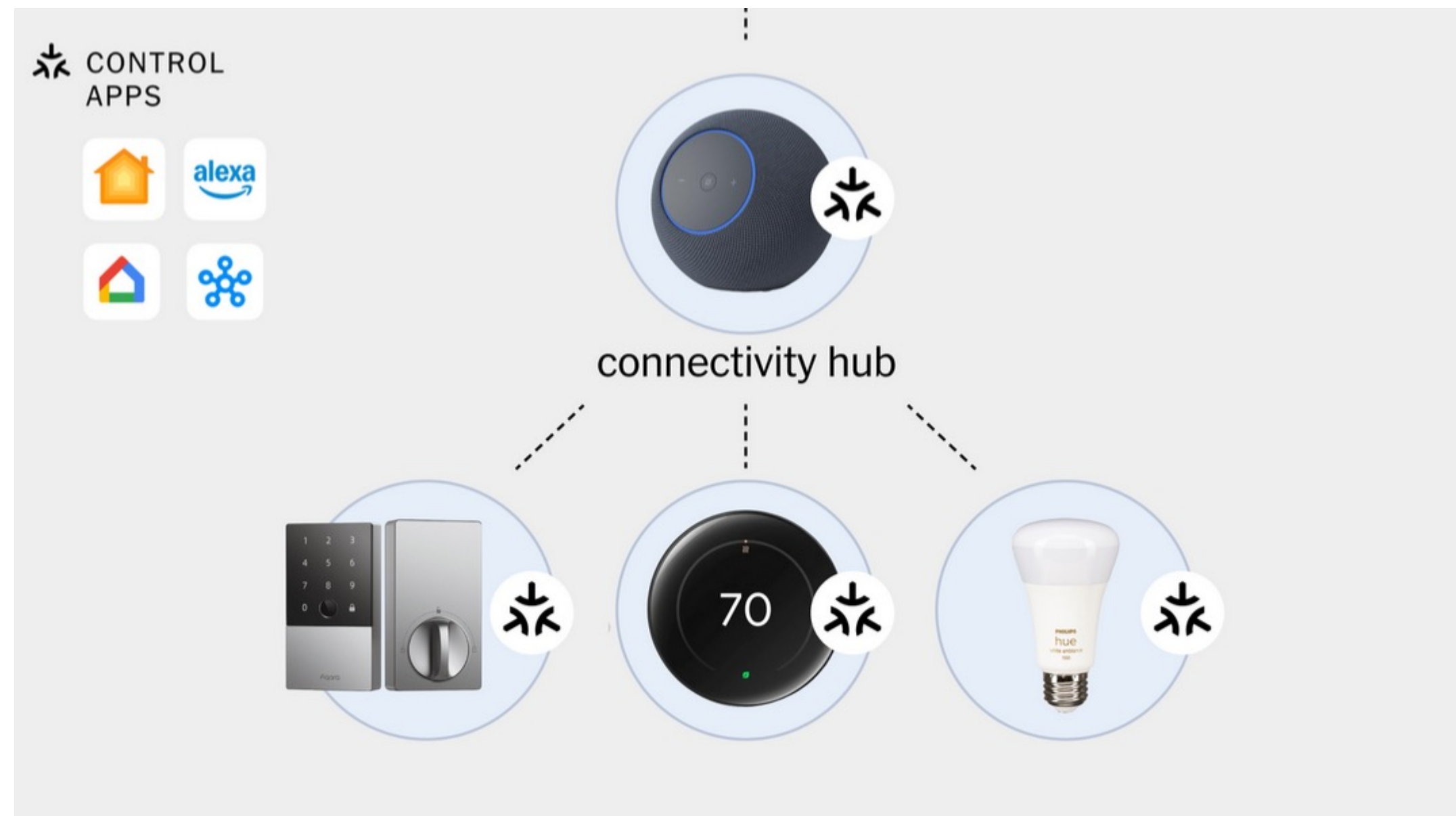
My Deconz stick died though and I switched to a Sonoff USB 3 Zigbee dongle.

Now I'm figuring out how to get light switches to control the lights. The only way I can see how to do it (with my limited knowledge) is to create separate automations for 1) switching the light on 2) switching it off 3) raising the illumination 4) lowering the illumination.

4 automations for every single light group, just seems very complex and time consuming to set up for something so simple and commonplace.

Is there a simpler way to associate light switches with light groups with default behaviors?

How do IoT devices from multiple sources cooperate? Badly.



That Curious Logo on Your Dryer Means It Can Do Smart Home Things

Updated January 22, 2026

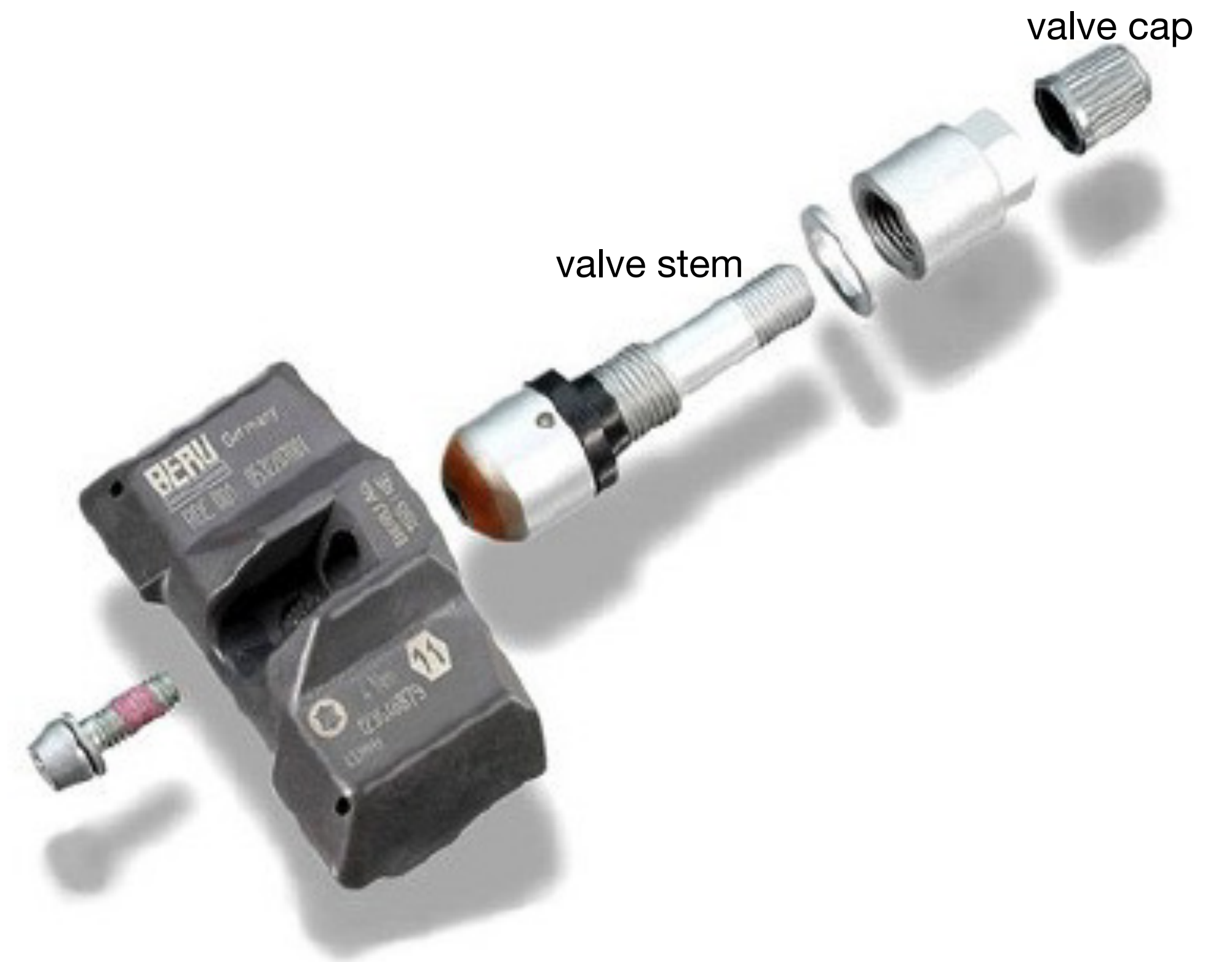
Where Matter still falls short

Our experience in using Matter-enabled devices is that even with steady updates it continues to be maddeningly nonuniform.

<https://www.nytimes.com/wirecutter/reviews/what-you-need-to-know-about-matter/>

AI + IoT Use Case Applications

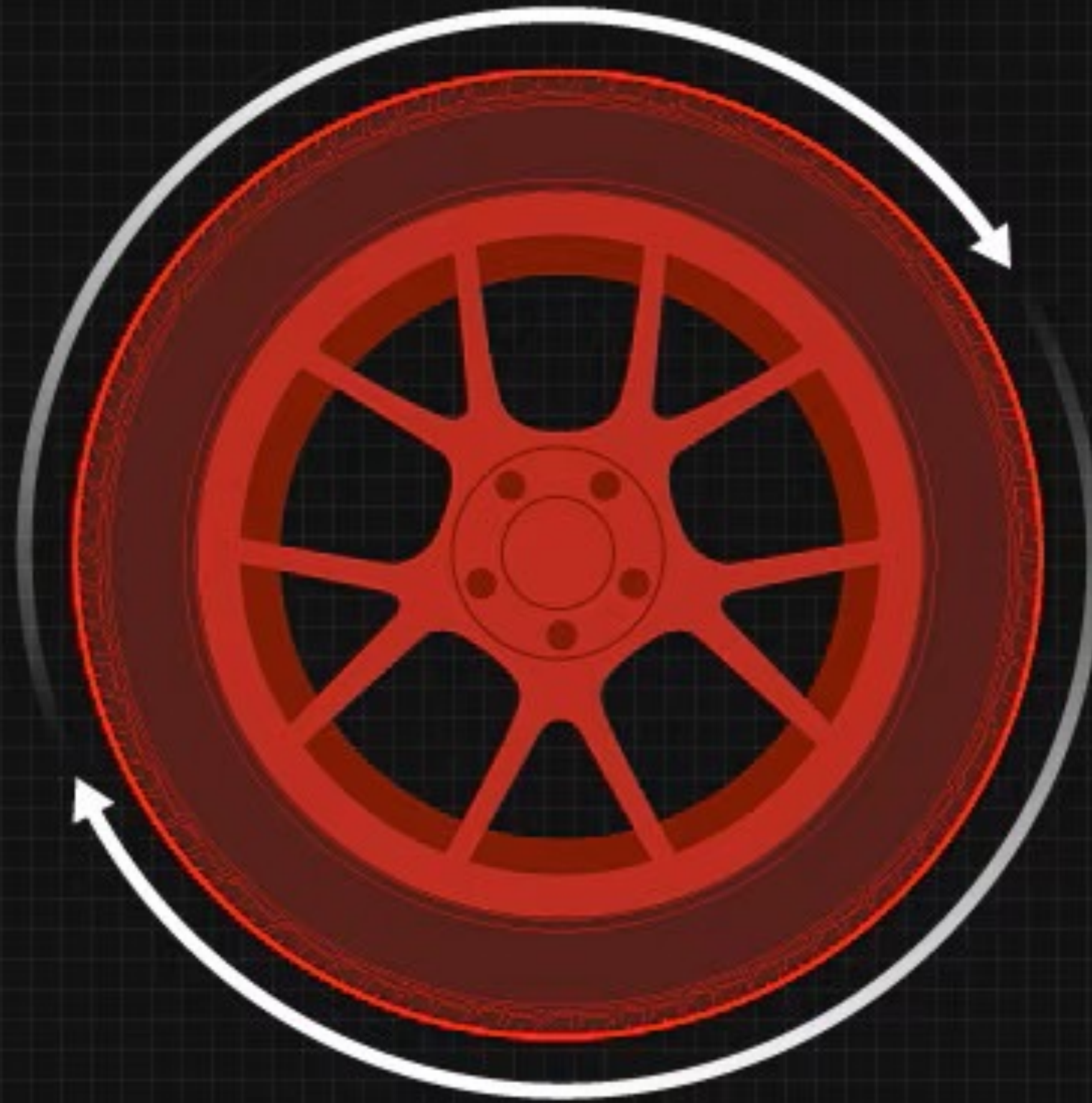
Measuring tire pressure saves lives and reduces carbon emissions.



Pep Boys
Auto Service & Tires

You can also indirectly measure a tire's pressure.

INDIRECT TPMS



- Tire pressure measured from rate of wheel revolution
- May be inaccurate if new tires are a different size
- Typically less expensive than direct TPMS
- Must reset after every tire rotation and/or inflation

TPMS creates privacy risks.

Can't Hide Your Stride: Inferring Car Movement Patterns from Passive TPMS Measurements

Yago Lizarribar[§]
armasuisse

Alessio Scalingi
Universidad Carlos III de Madrid

Domenico Giustiniano
IMDEA Networks

Pedro Miguel Sánchez Sánchez
University of Murcia

Roberto Calvo-Palomino
Universidad Rey Juan Carlos

Gérôme Bovet
armasuisse

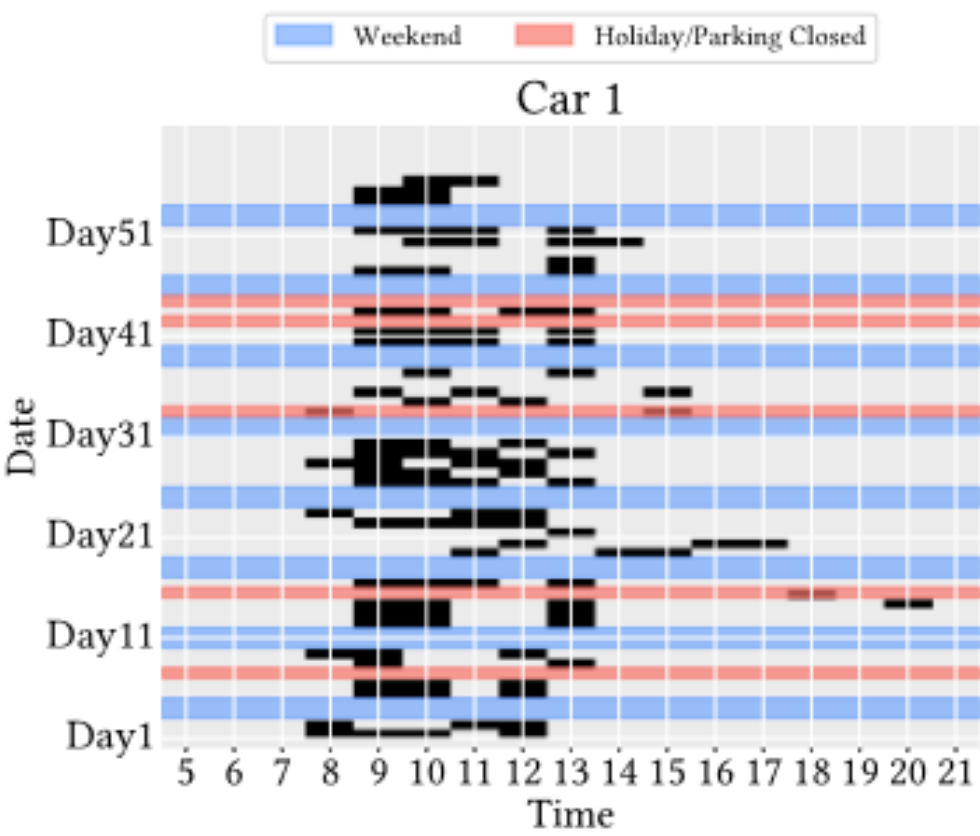
Vincent Lenders
University of Luxembourg



(a) Spectrum receiver setup.



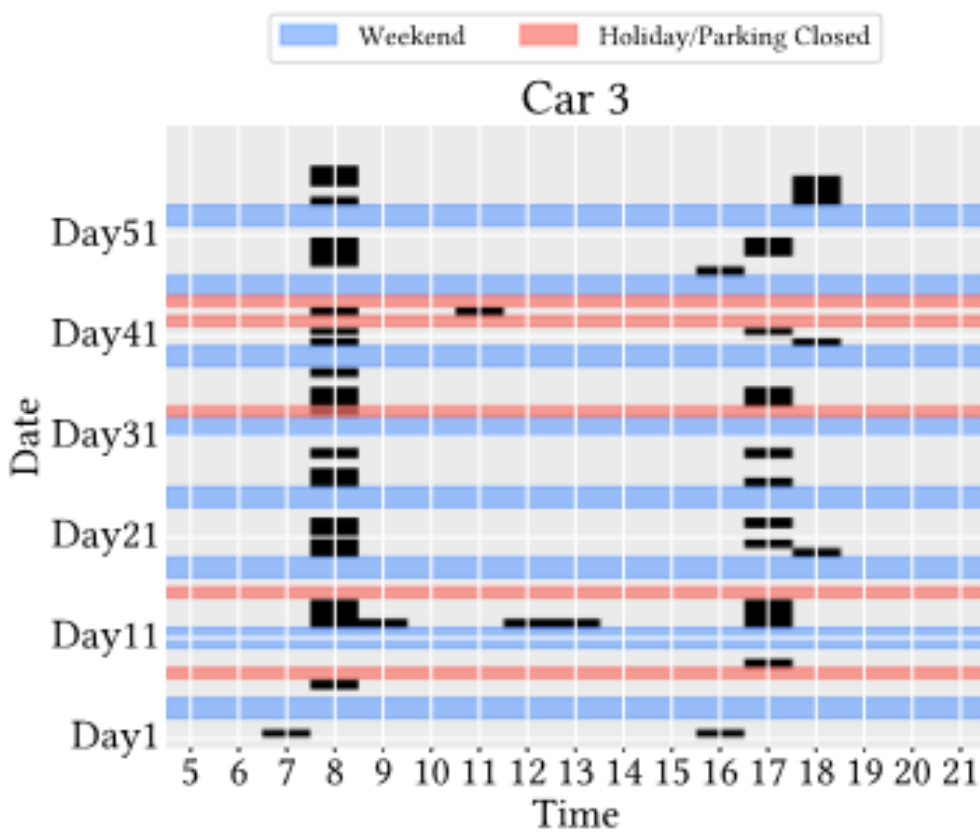
(b) Receiver deployment.



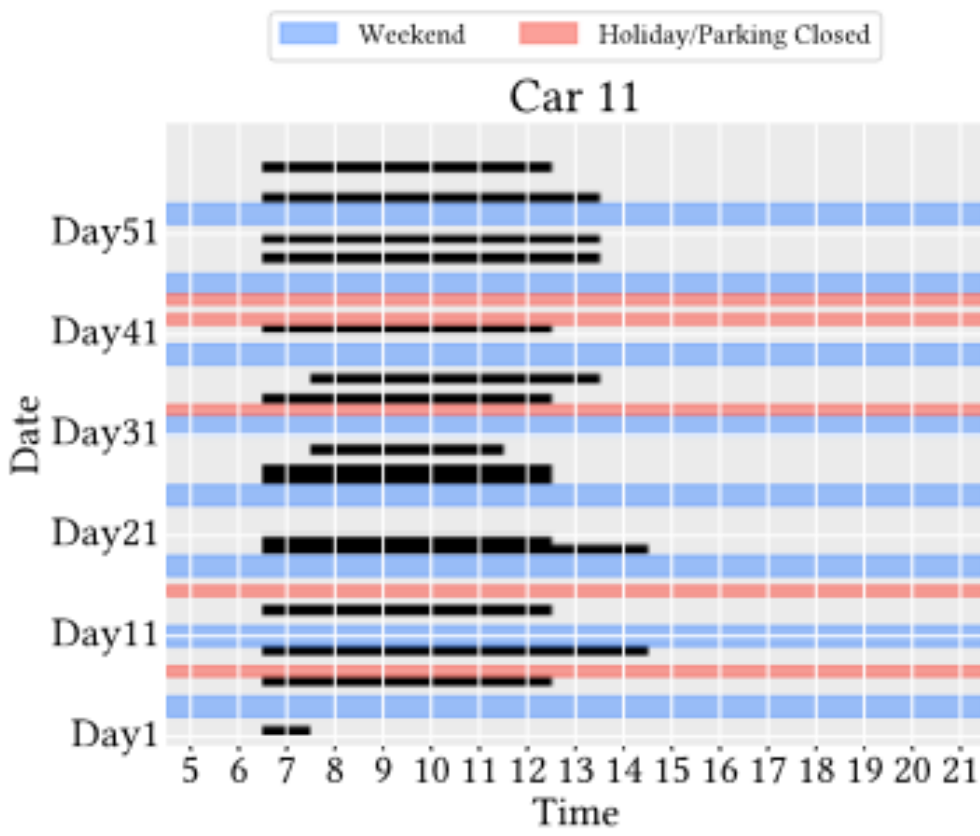
(a) PT Worker.



(c) External Worker.

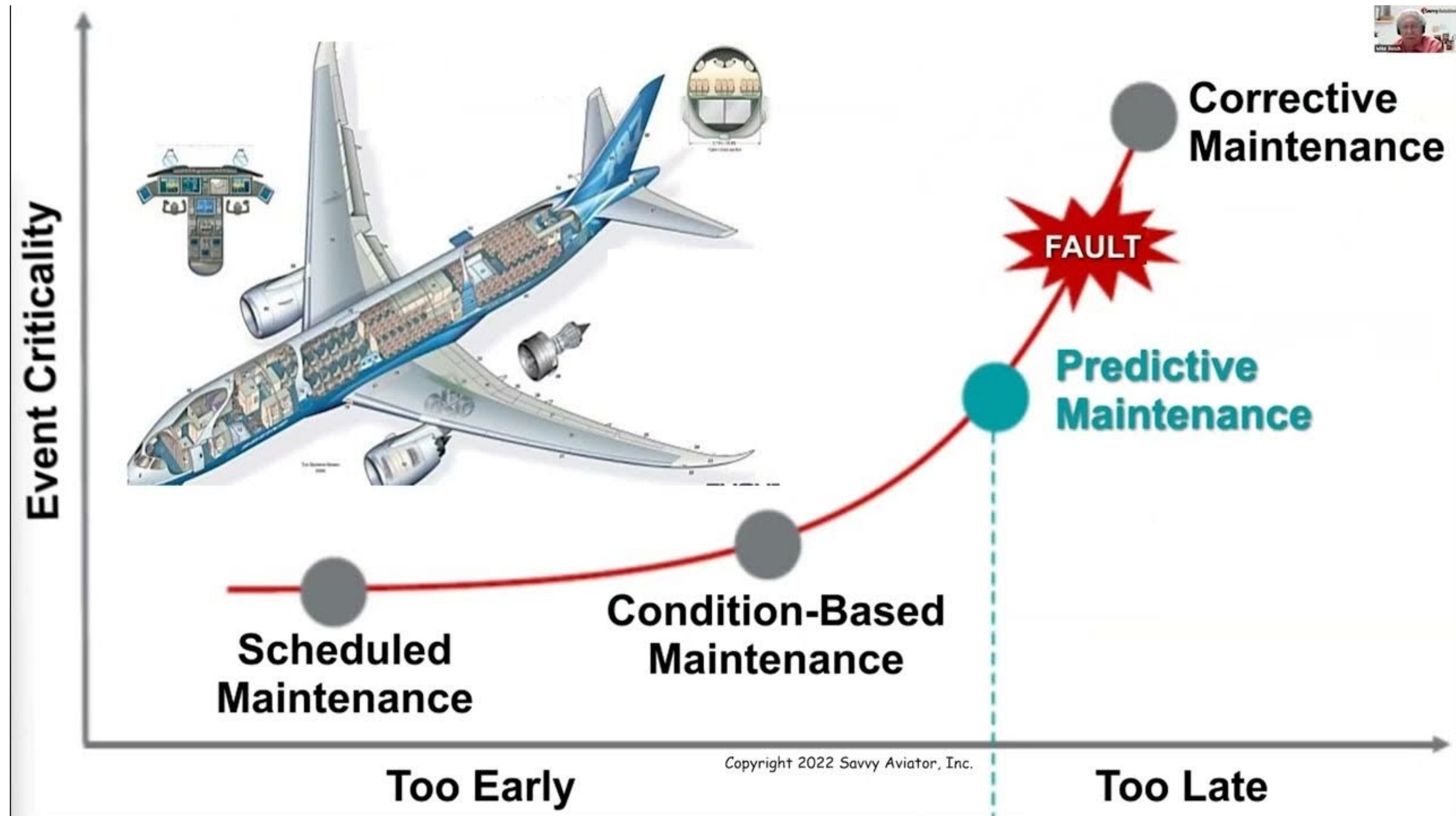


(b) FT Worker.



(d) External PT Worker.

What if sensors could predict failure before it happened?



Traffic lights and CCTVs can be an IoT system controlling traffic.

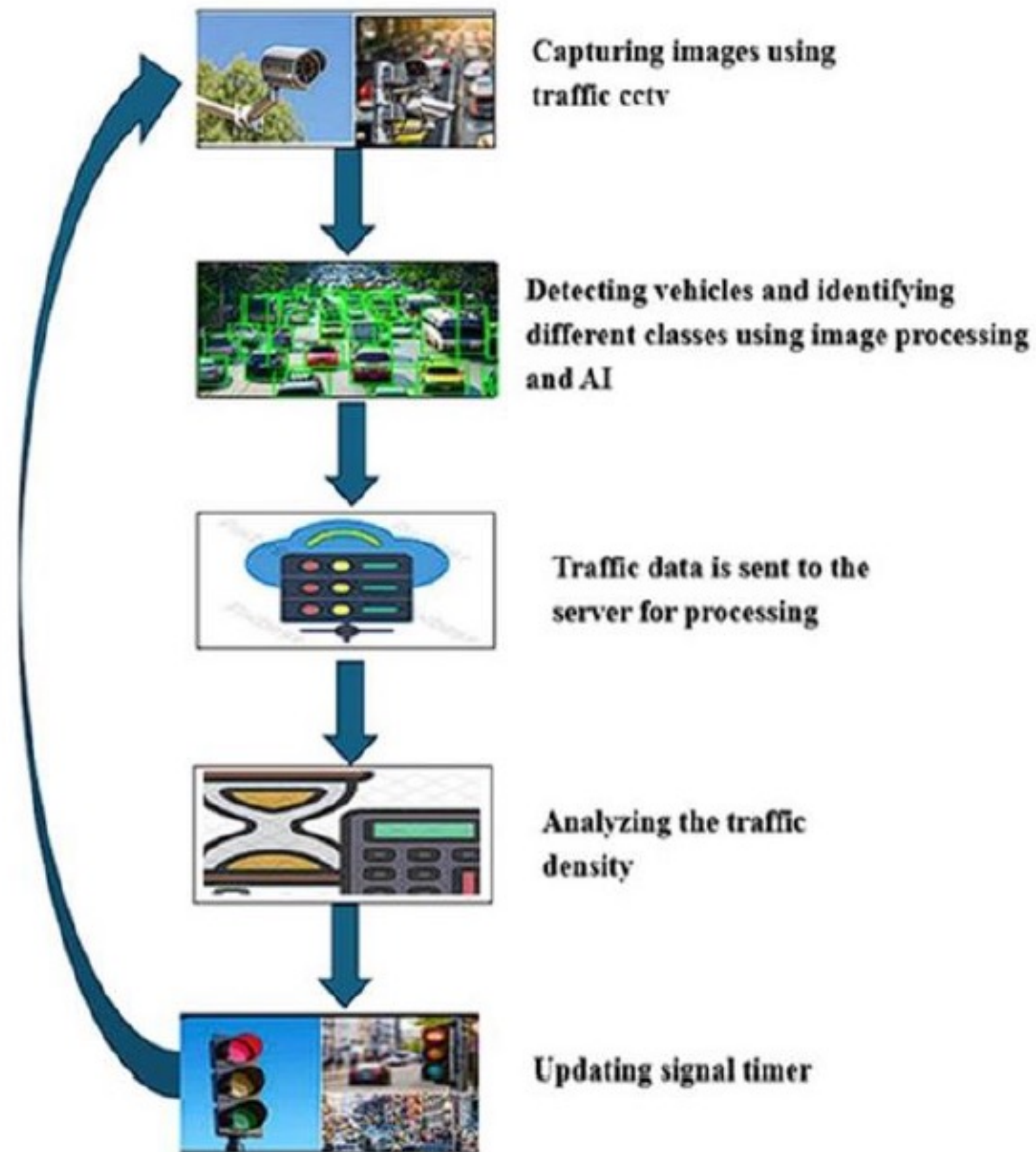
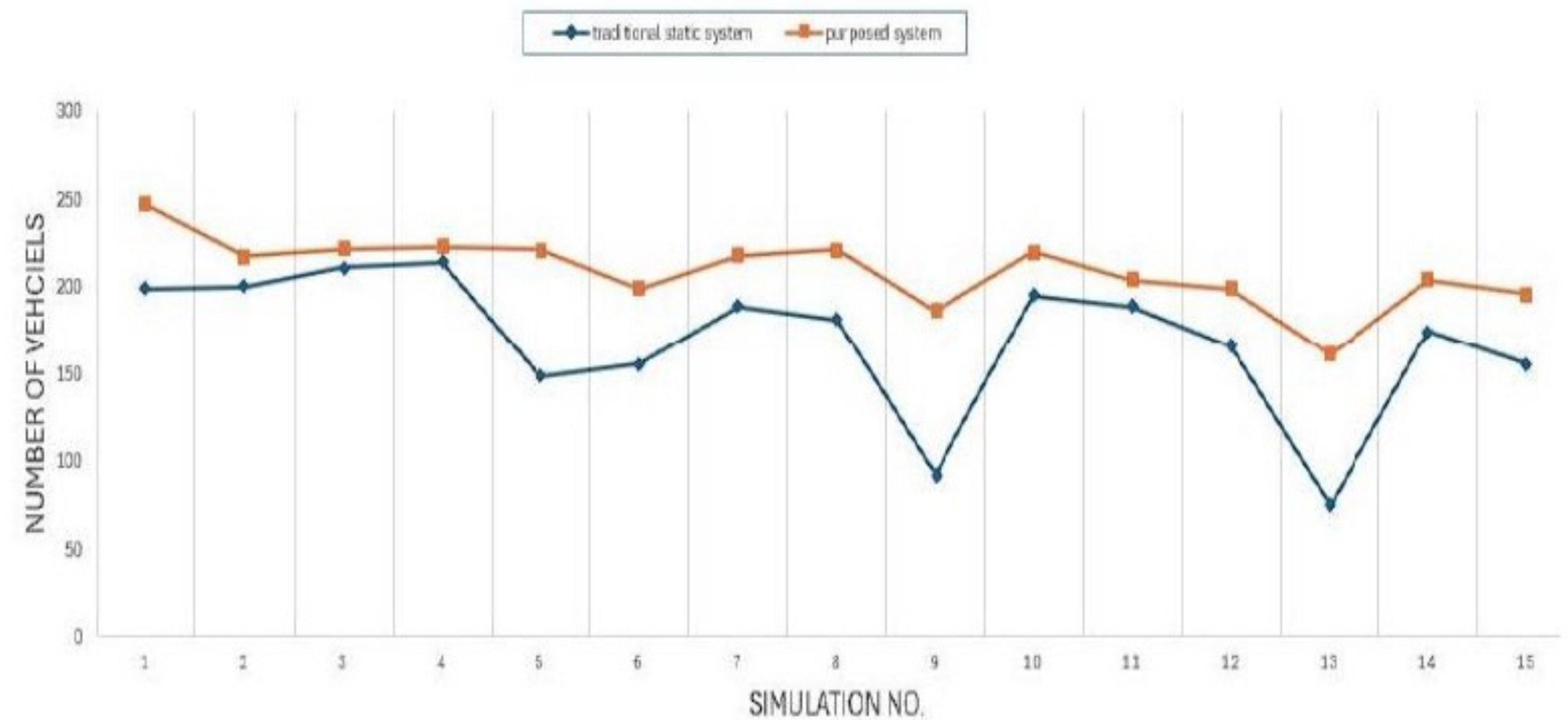
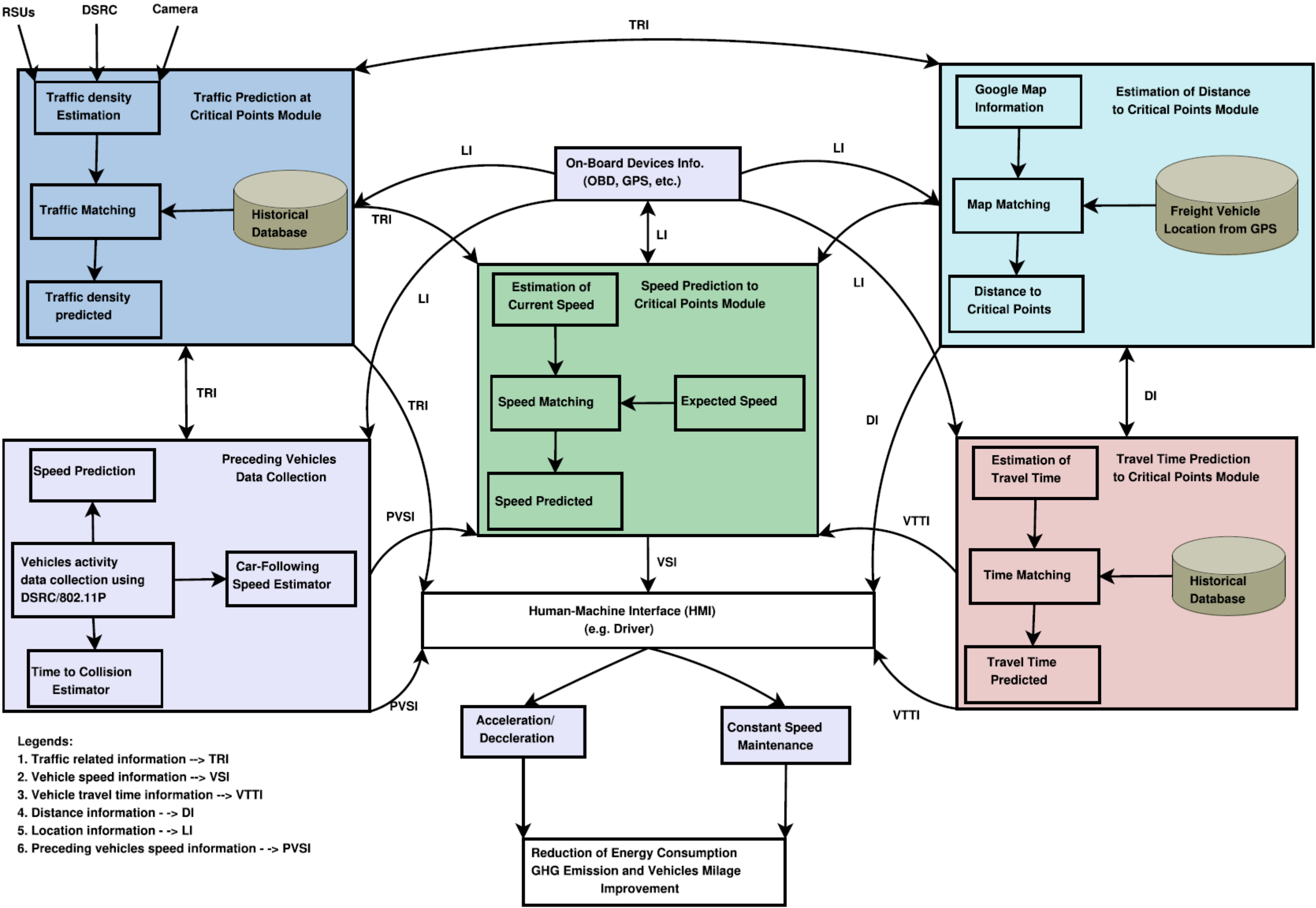


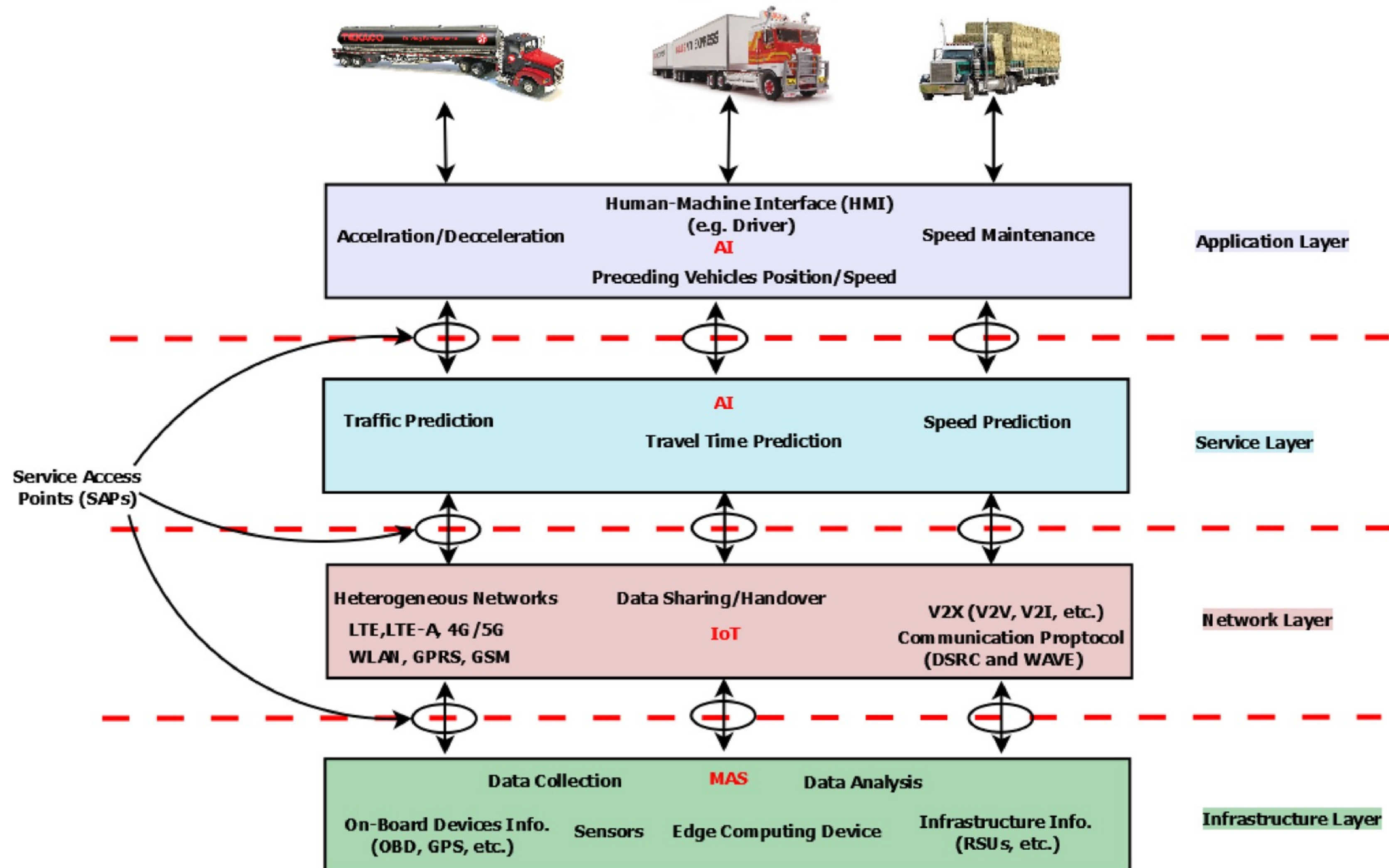
Figure 1. Flow diagram of the system.

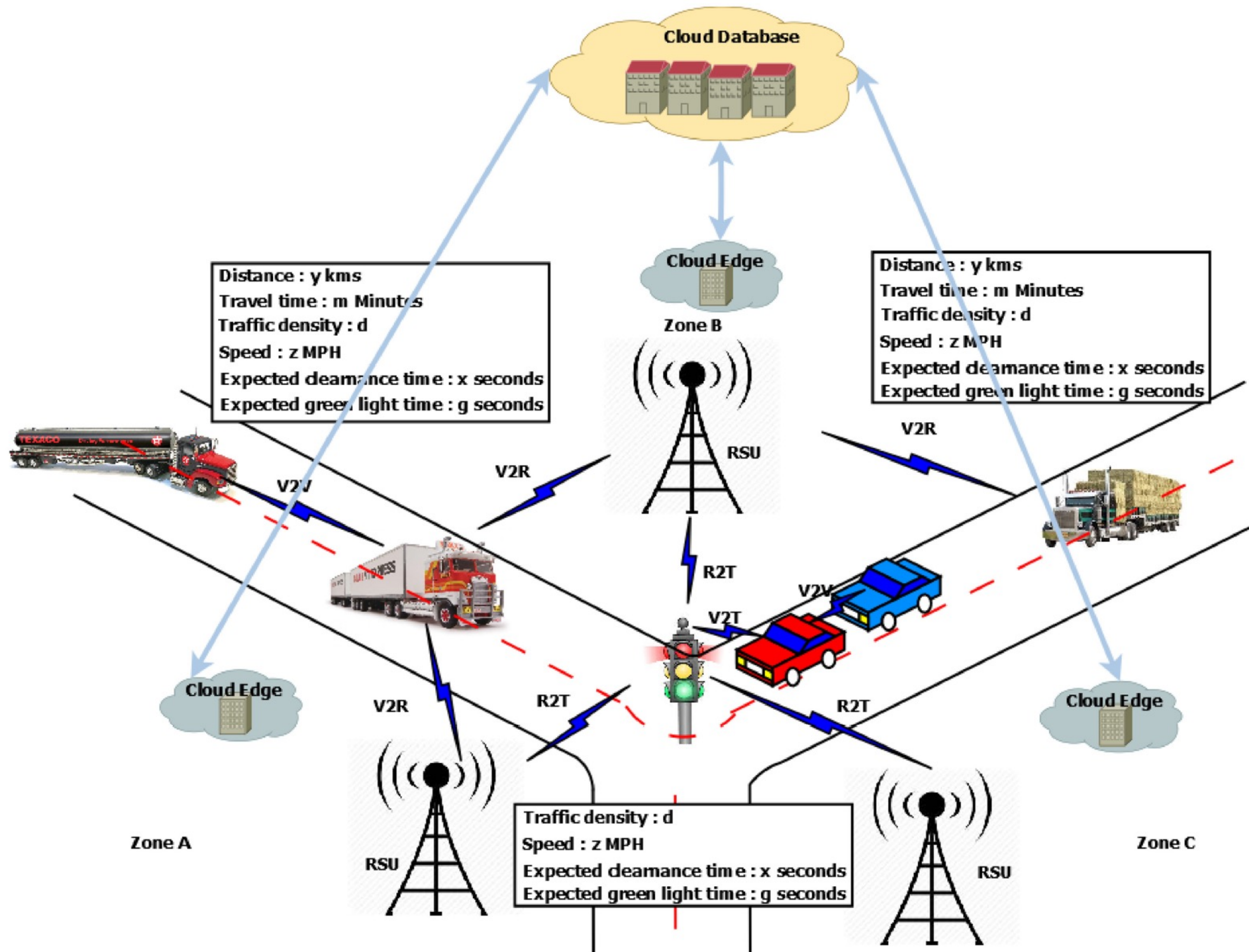


AI and IoT for Smart Cities, Take Two

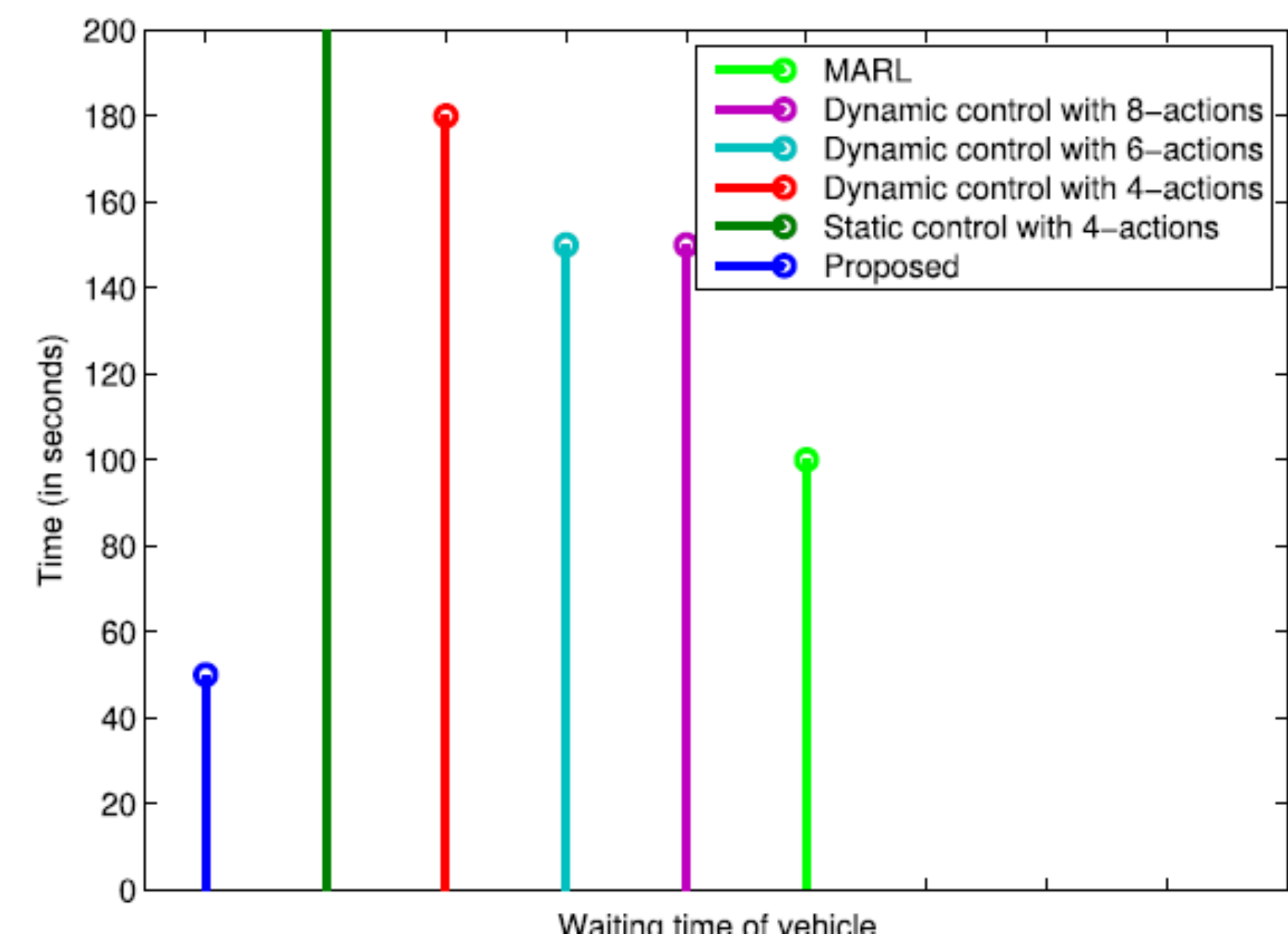
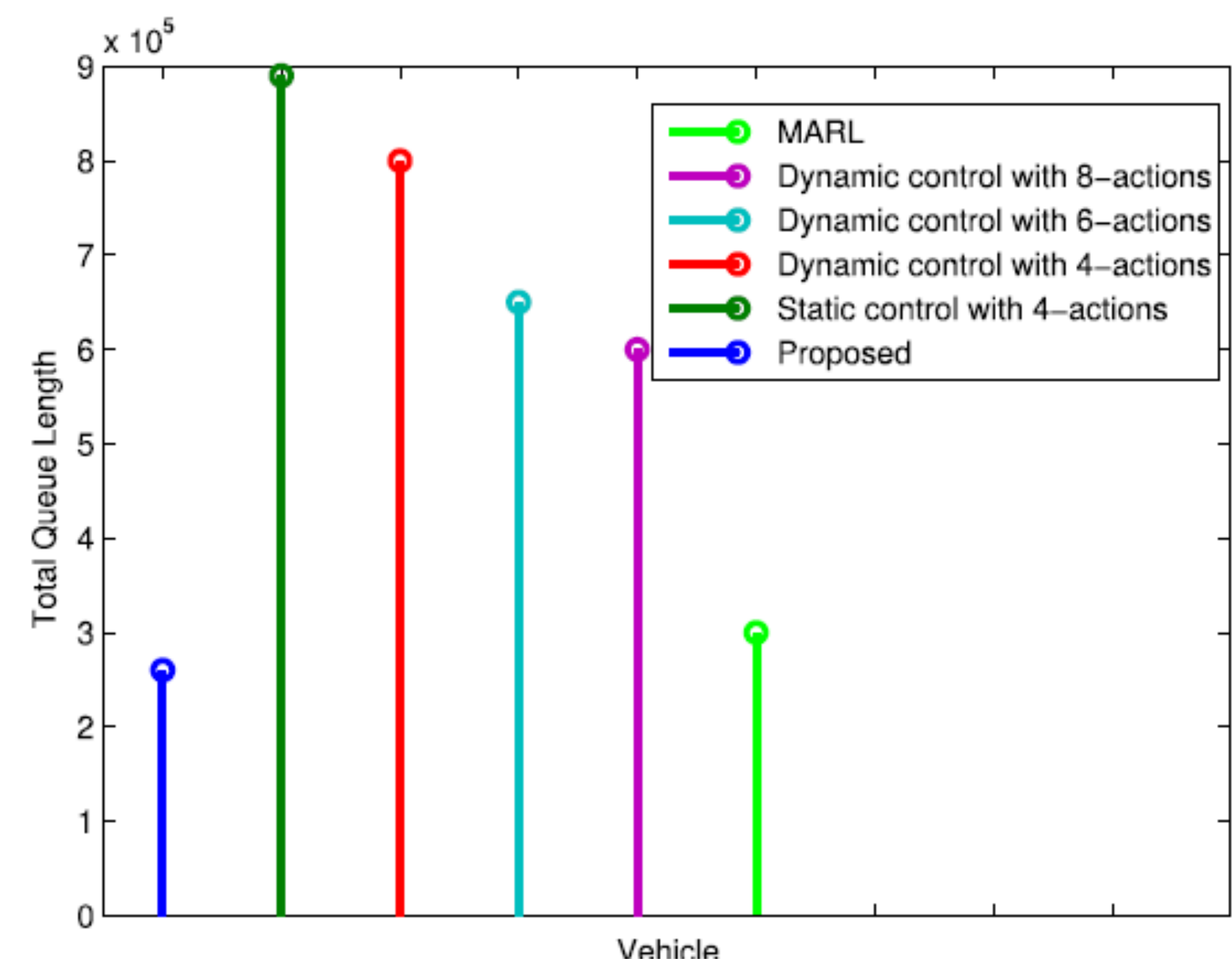


The system collects data on-board and floats it through the network.

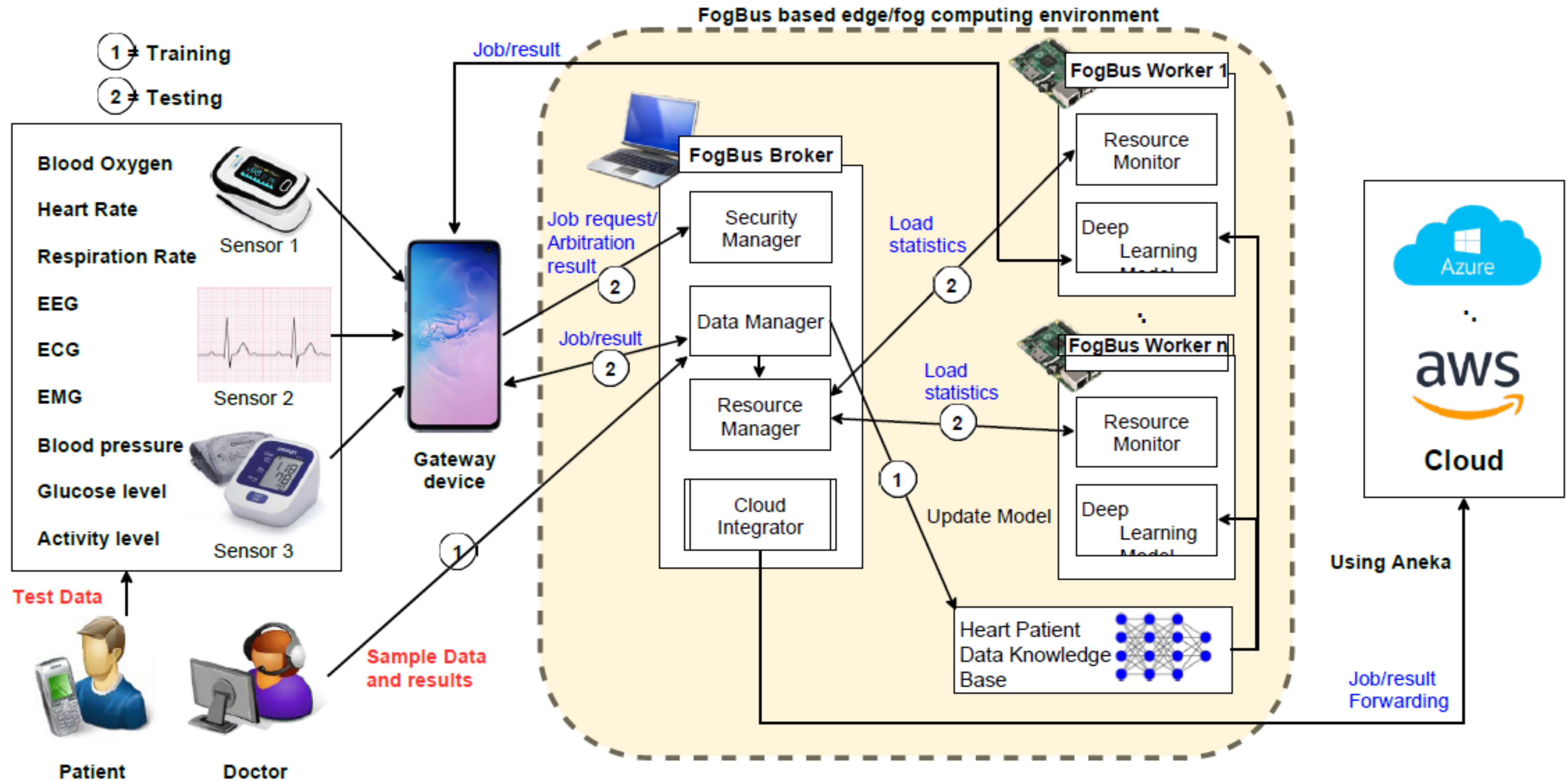




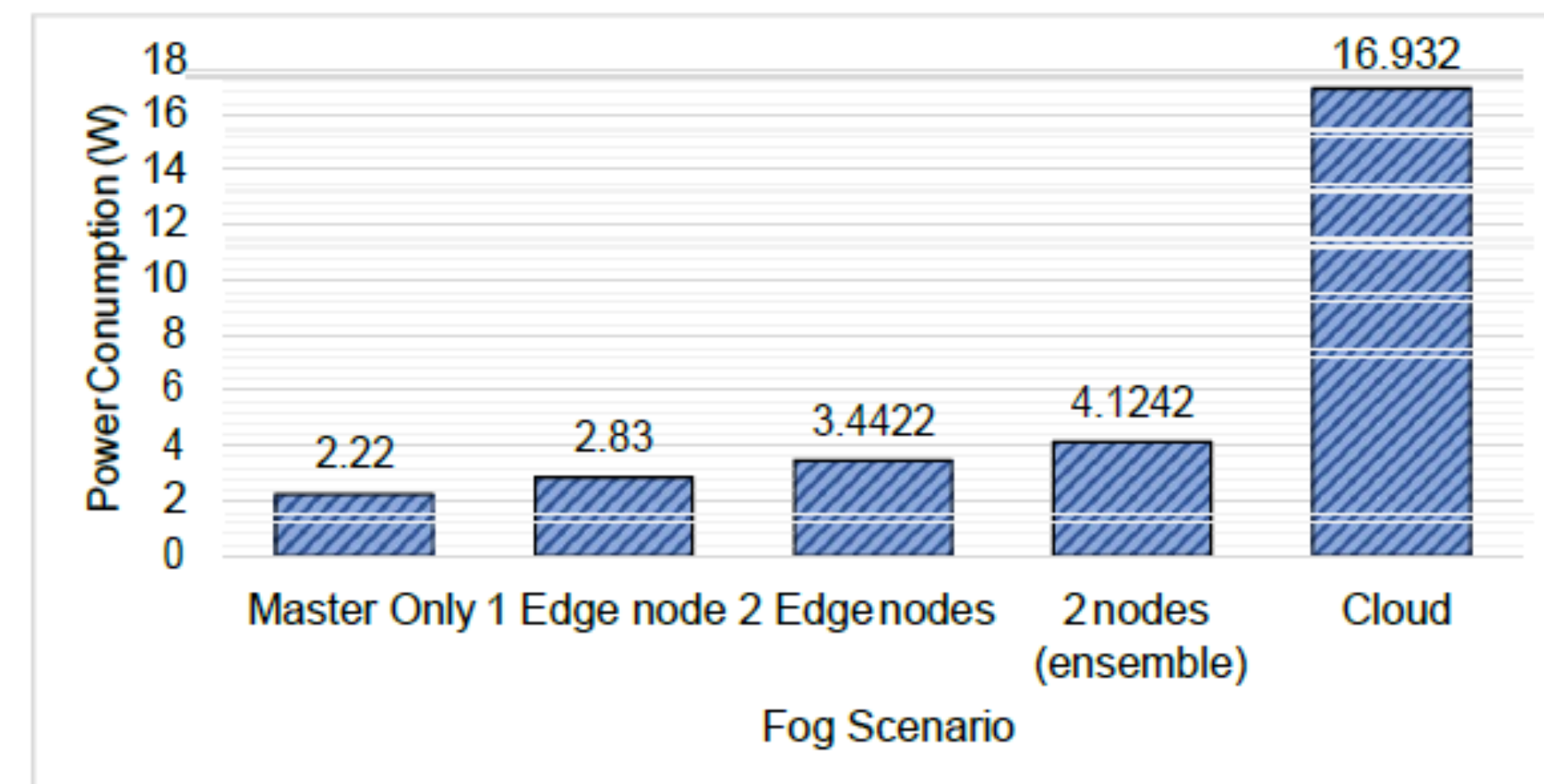
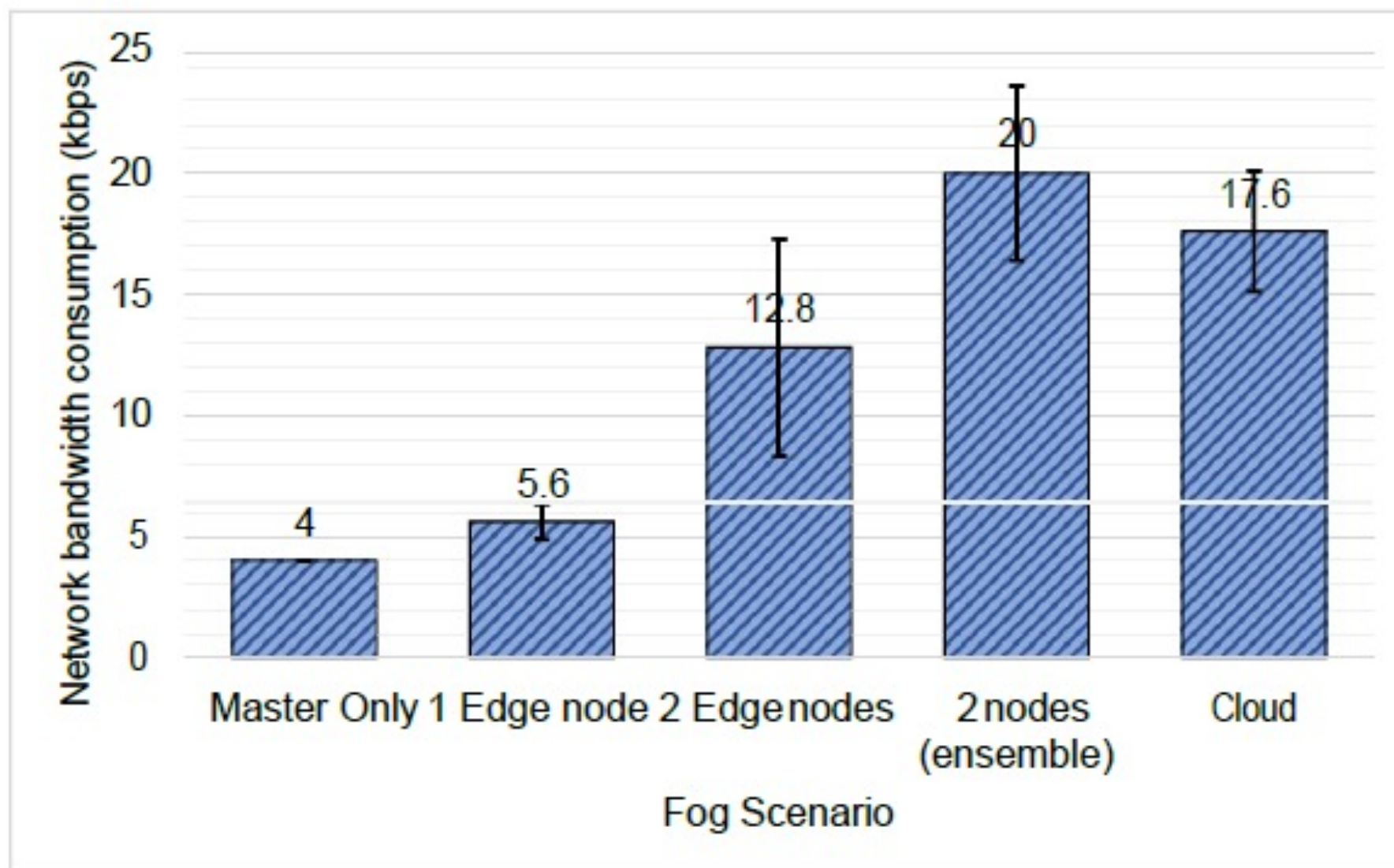
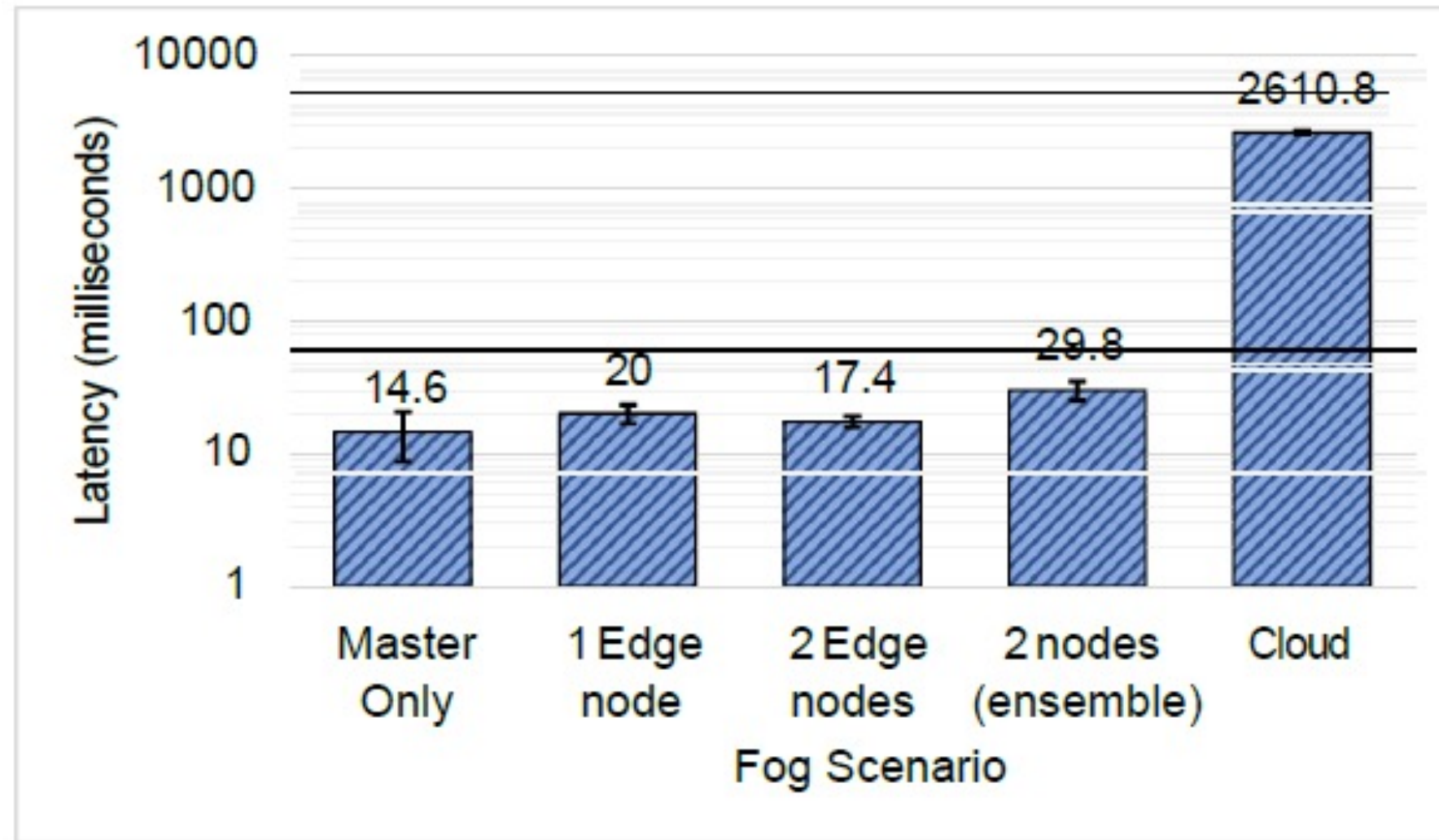
Simulated predictions of queue length for freight vehicles



IoT and AI in a health care context

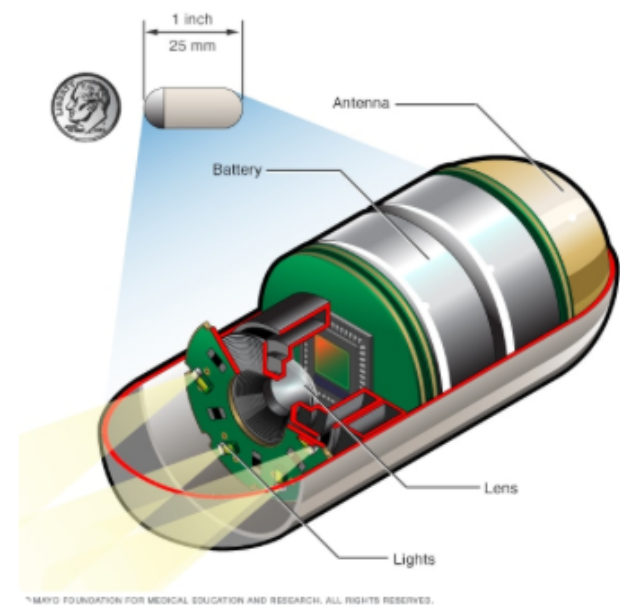


Performance characteristics of Health-IoT system



Capsule Endoscopy!

Overview



Capsule endoscopy camera

[Enlarge image](#)

Capsule endoscopy is a procedure that uses a tiny wireless camera to take pictures of the organs in the body that food and liquids travel through. This is called the digestive tract. A capsule endoscopy camera sits inside a vitamin-sized capsule. After it's swallowed, the capsule travels through the digestive tract. The camera takes thousands of pictures that are sent to a recorder worn on a belt around the waist.

<https://www.mayoclinic.org/tests-procedures/capsule-endoscopy/about/pac-20393366>



YouTube

Search



Adam Savage Swallows This Camera Robot!



Adam Savage's T...
6.92M subscribers

Join

Subscribe

50K



Share



2.8M views 10 months ago #adamsavage #science #pillbot

This may be the smallest remote controlled robot we've covered on Tested. Adam visits the workshop of Endiatx, the makers of the Pillbot robotic endoscope that can swim around in your stomach to map and examine your insides. Adam swallows not just one, but two Pillbots during his visit and pilots the robots around his own stomach! ...more

<https://www.youtube.com/watch?v=FmE93ox9e2c>

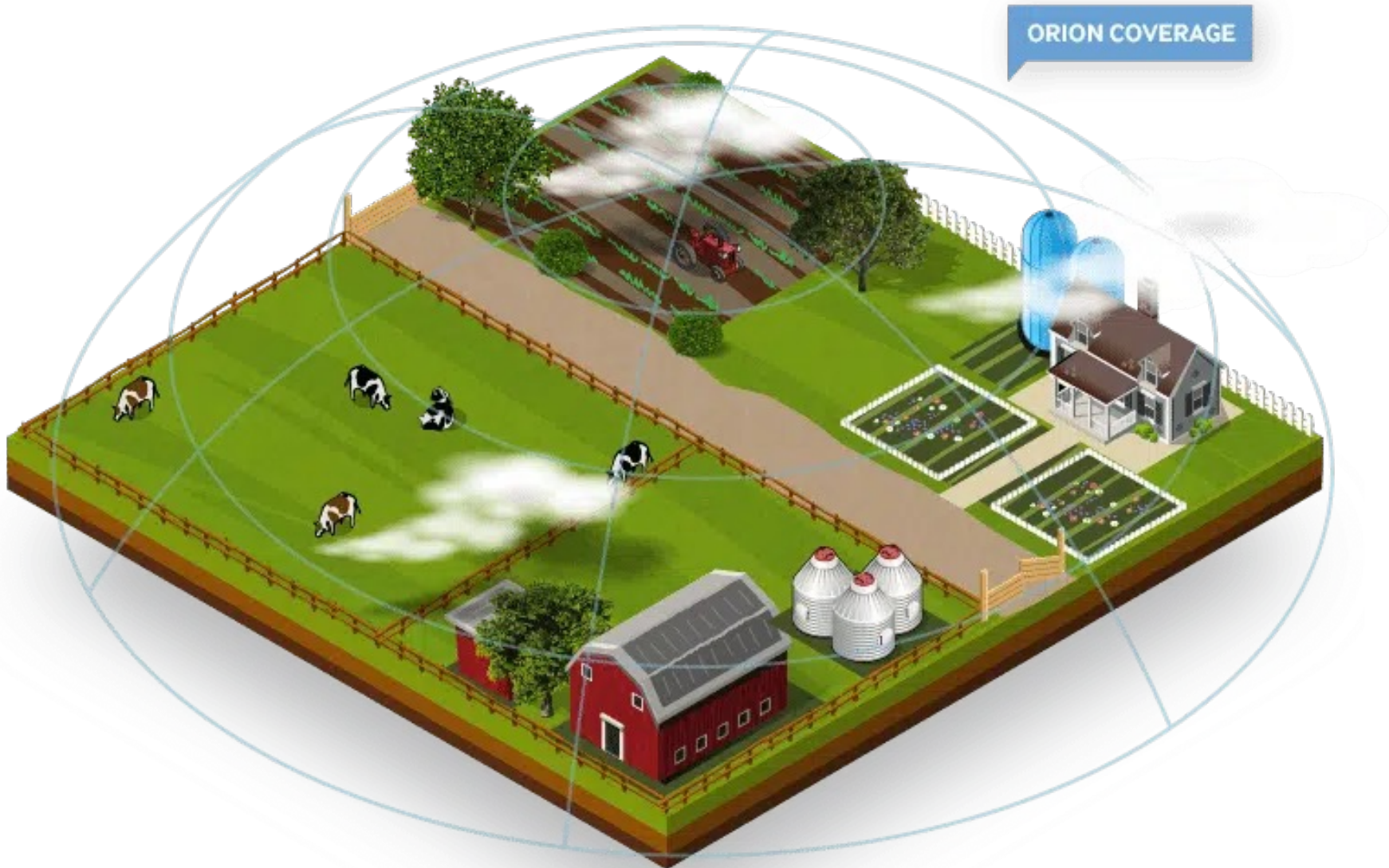
IoT and Agriculture

Examples of emerging precision agriculture technologies

Technology	Description
Remote sensing platforms	Drones and ground robots can provide new ways to provide measurements on crop conditions.
In-ground sensors	Provide farmers near-real-time information on soil and plant properties such as temperature, moisture, and nutrients.
Targeted spray systems	Use machine learning to precisely spray in a specific spot.
Automated mechanical weeders	Use machine learning to start and stop weeding blades to avoid damaging the growing crops.



implanted
5 year battery life
Wi-Fi
Transmits temperature



Precision Agriculture Technologies



Auto-guidance

A guidance system that steers agricultural equipment with accuracy within centimeters. Newer equipment has this technology embedded, and add-on systems can be retrofitted on older equipment. Auto-guidance can provide for near-total automated steering while in the field. With auto-guidance, equipment can repeatedly drive along designated paths. Sometimes referred to as auto-steer.



Soil mapping

Soil mapping is used to identify soil properties at different locations. With a soil map, a farmer can decide on actions to prepare soil for growing agricultural commodities or on alternative land use options. To create a soil map, different technologies exist, including:

- Soil sampling: measures soil factors including composition and nutrients. Though accurate, soil sampling can be expensive for large fields given the large number of samples required to generate an accurate soil map.
- Electromagnetic sensing: measures the electrical characteristics of the soil, which reflect the soil's composition.
- In situ sensors: can measure soil moisture.



Yield monitors and yield mapping

Yield monitors measure the harvest of a crop and tag the yield with a latitude and longitude coordinate. Data from the yield monitor are used to create a yield map to quantify and characterize within-field production variability. Yield monitors are widely available for field crops, but they are not widely available for specialty crops. Other techniques such as overhead imagery can estimate crop yields for specialty crops.



Plant measurements

Plant characteristics can be measured by calculating vegetative indices using components of the electromagnetic spectrum. These indices provide estimates of characteristics, such as the amount of live green vegetation. Measurements are normally made remotely, with satellites, airplanes, or uncrewed aerial vehicles.

Agg drones for crop monitoring and spraying

APR 20, 2023

Fully autonomous drone introduced for large scale farm operations

✉ Hylío has introduced a fully autonomous drone for large scale agricultural operations.

f The AG-130 has an 8.0-gallon tank capacity with an application rate of up to 50 acres per hour, according to the release.



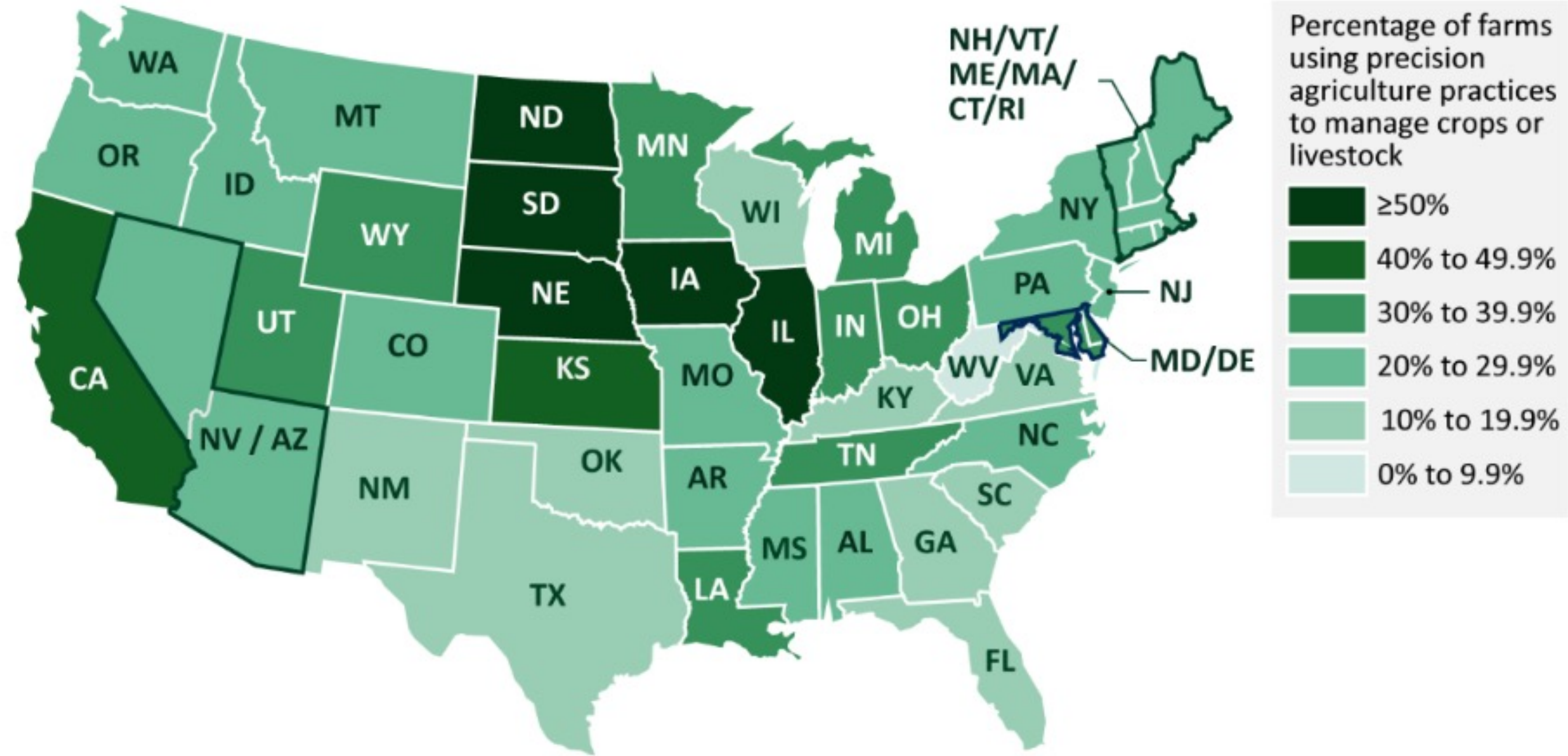
The AG-130 possesses an eight-rotor unmanned aircraft systems (UAS) platform equipped with a high-precision spraying system consisting of two 4.0-gallon tanks, air-induction nozzles, and electronic flowmeters. It has two wide-angle radars, a built-in HD camera and two GPS units.



<https://fruitgrowersnews.com/news/fully-autonomous-drone-introduced-for-large-scale-farm-operations/>

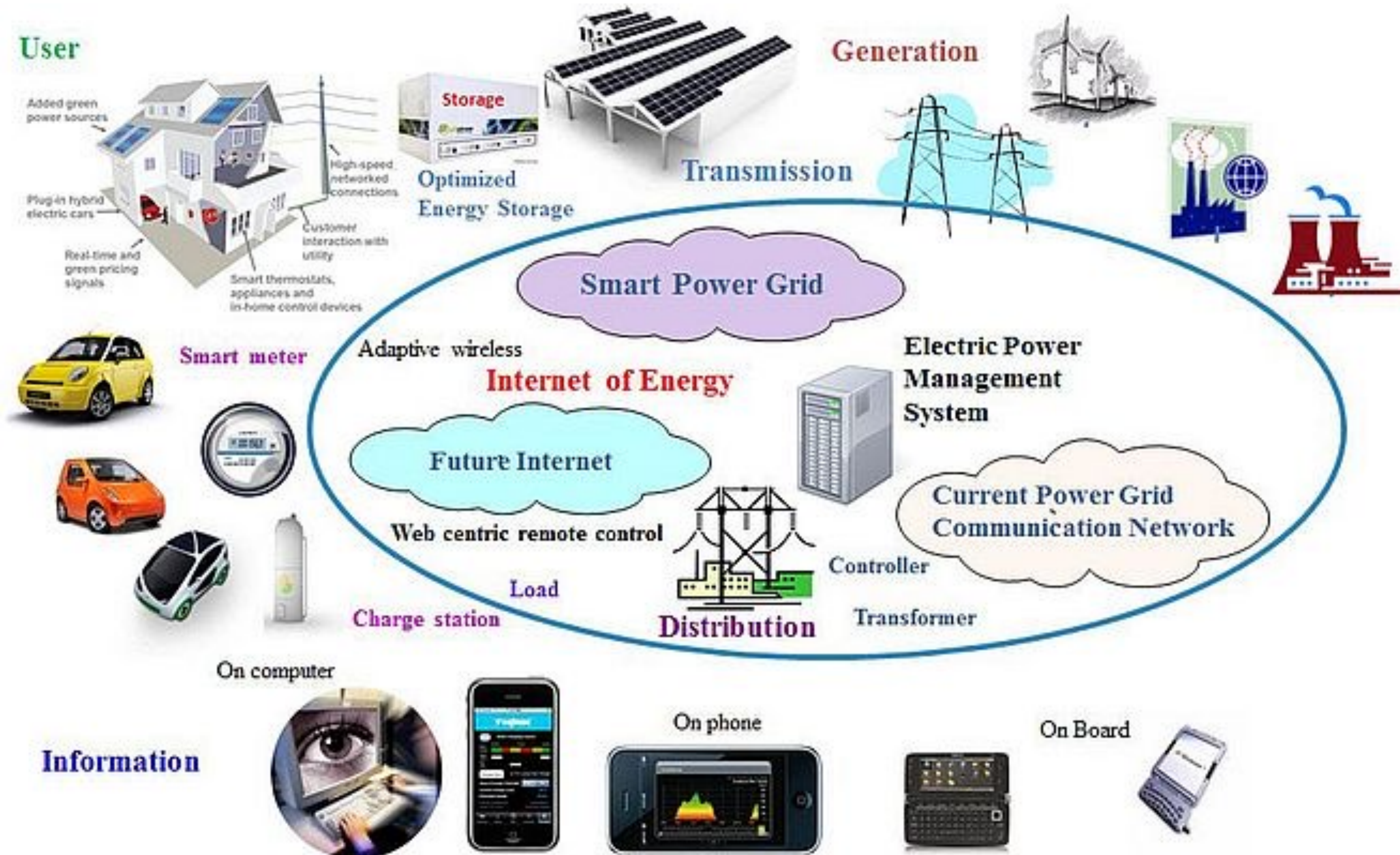
Use of precision agriculture in U.S.

Use of precision agriculture practices by U.S. farms, June 2022–June 2023



Source: GAO summary of data reported in 2023 by the U.S. Department of Agriculture; Map Resources (map). | GAO-24-105962

The “Internet of Energy”

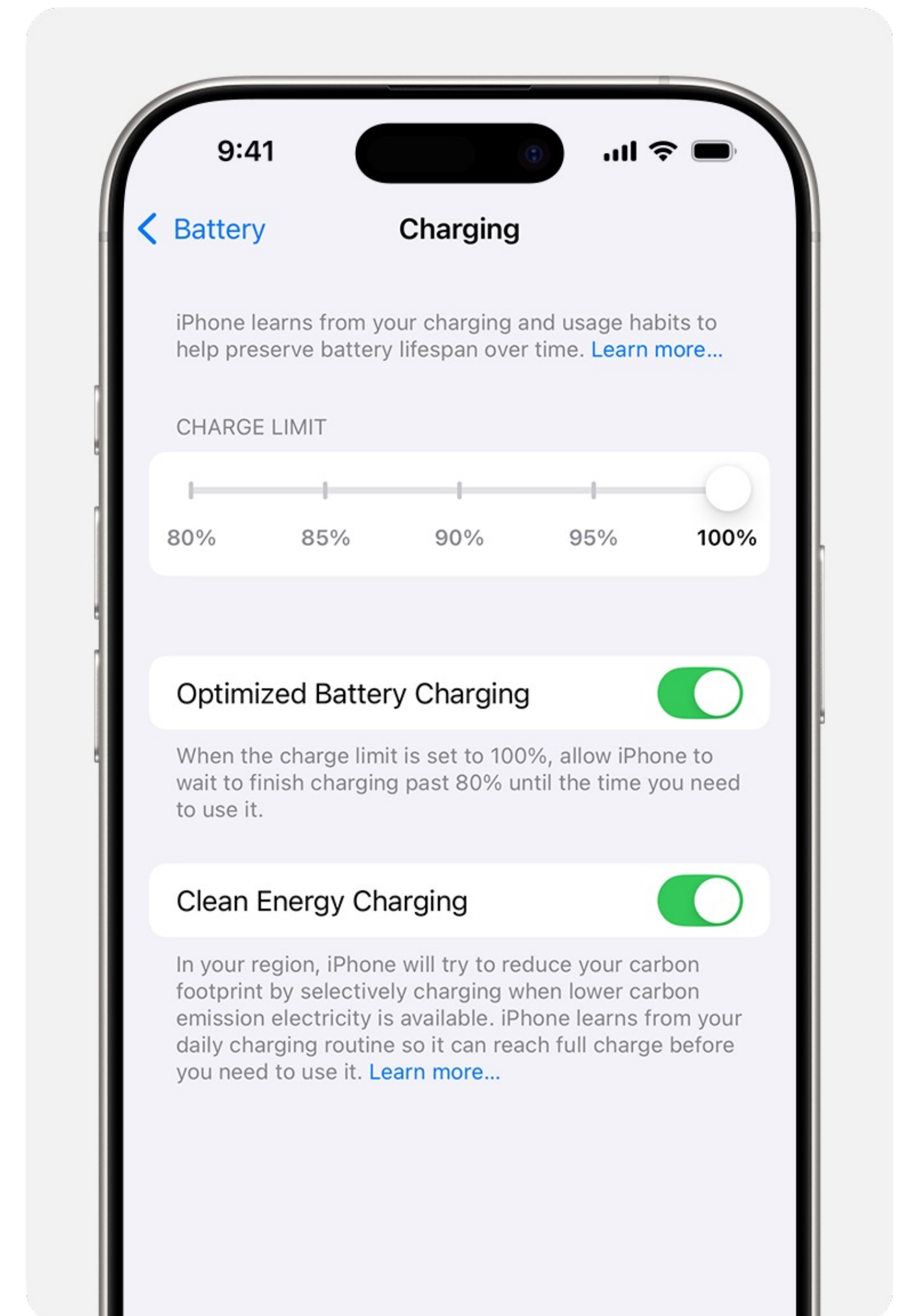


Examples of the smart power grid today



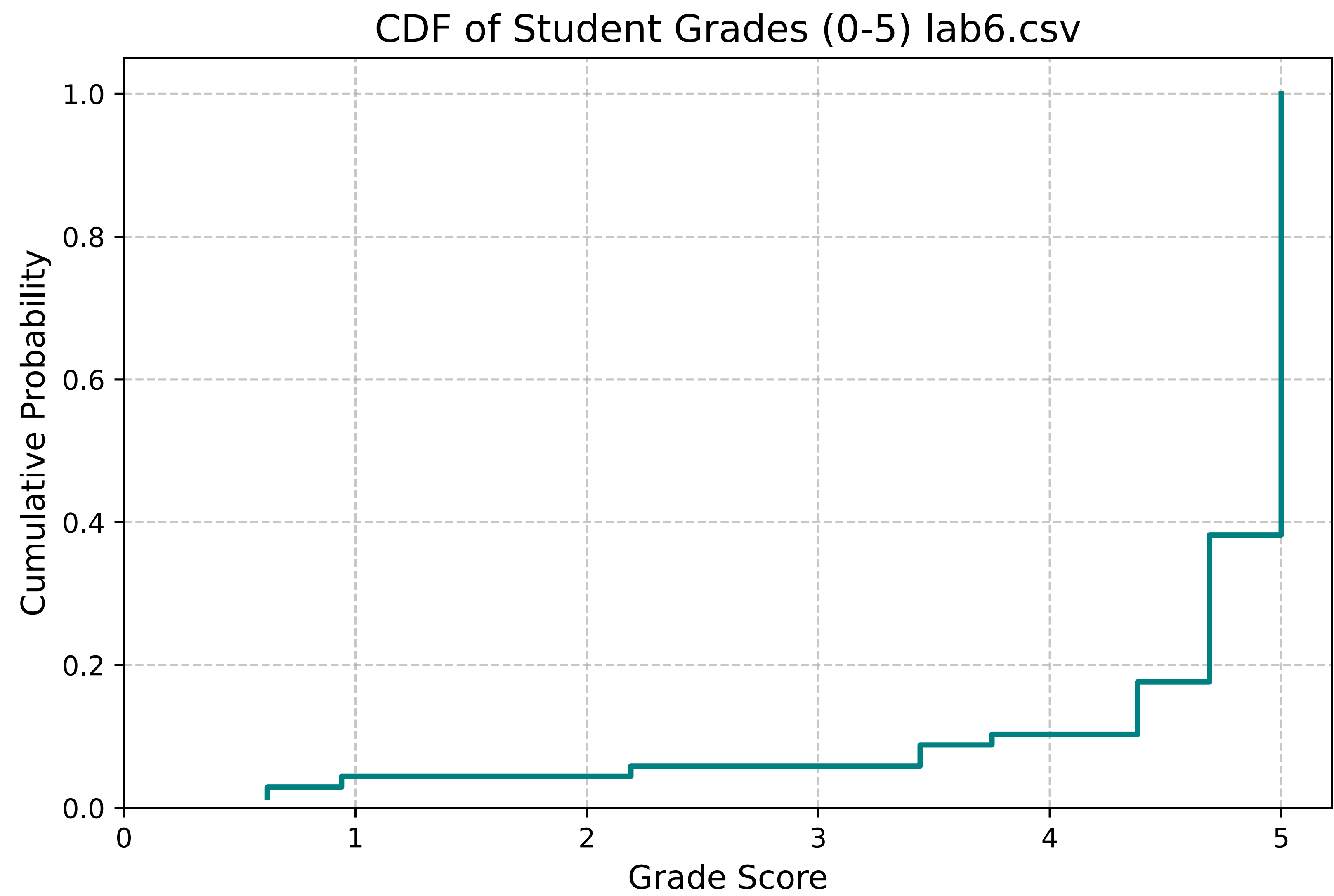
Relion® 630 series

Load-shedding controller PML630
High performing load-shedding solution
for industrial and utility power networks

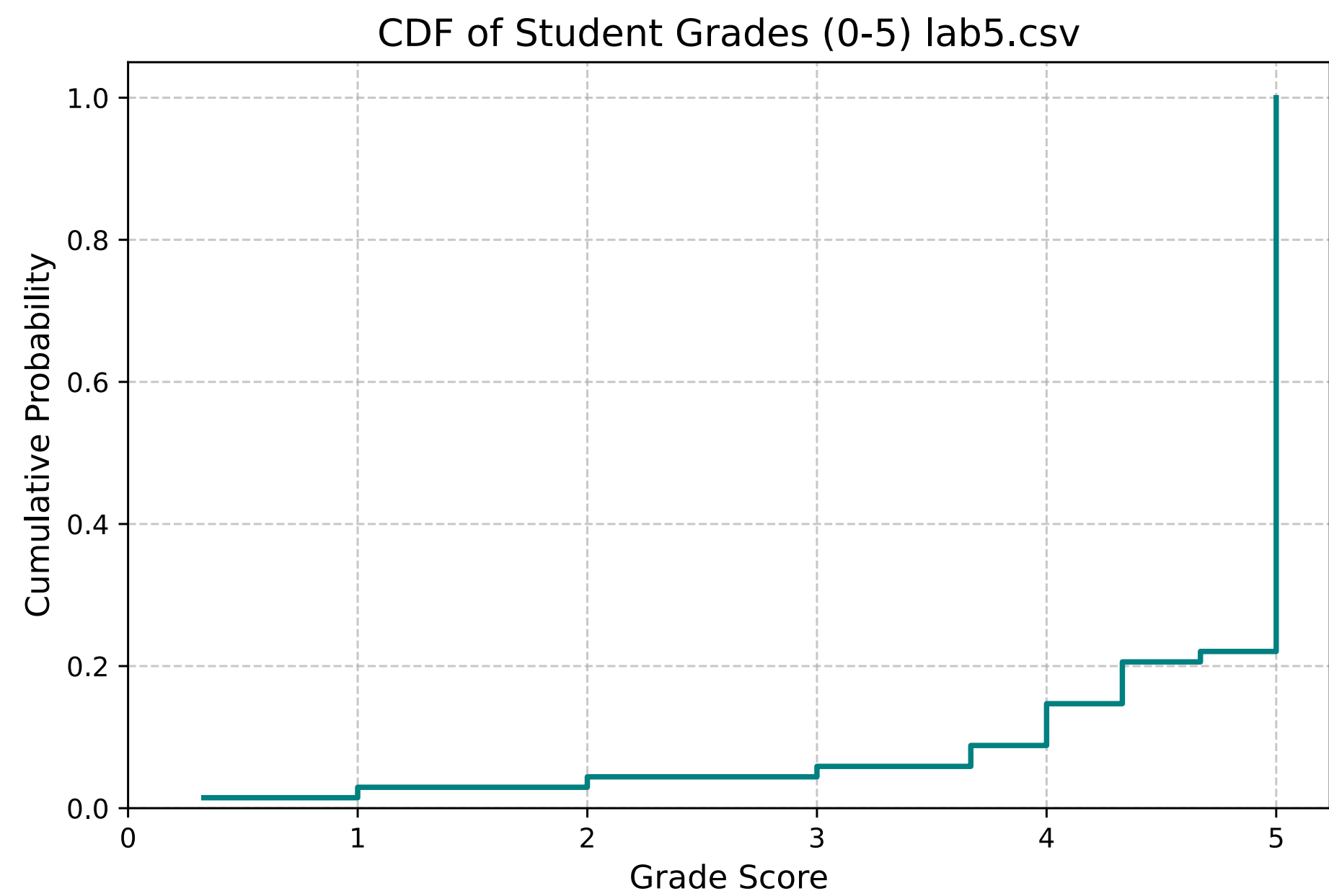
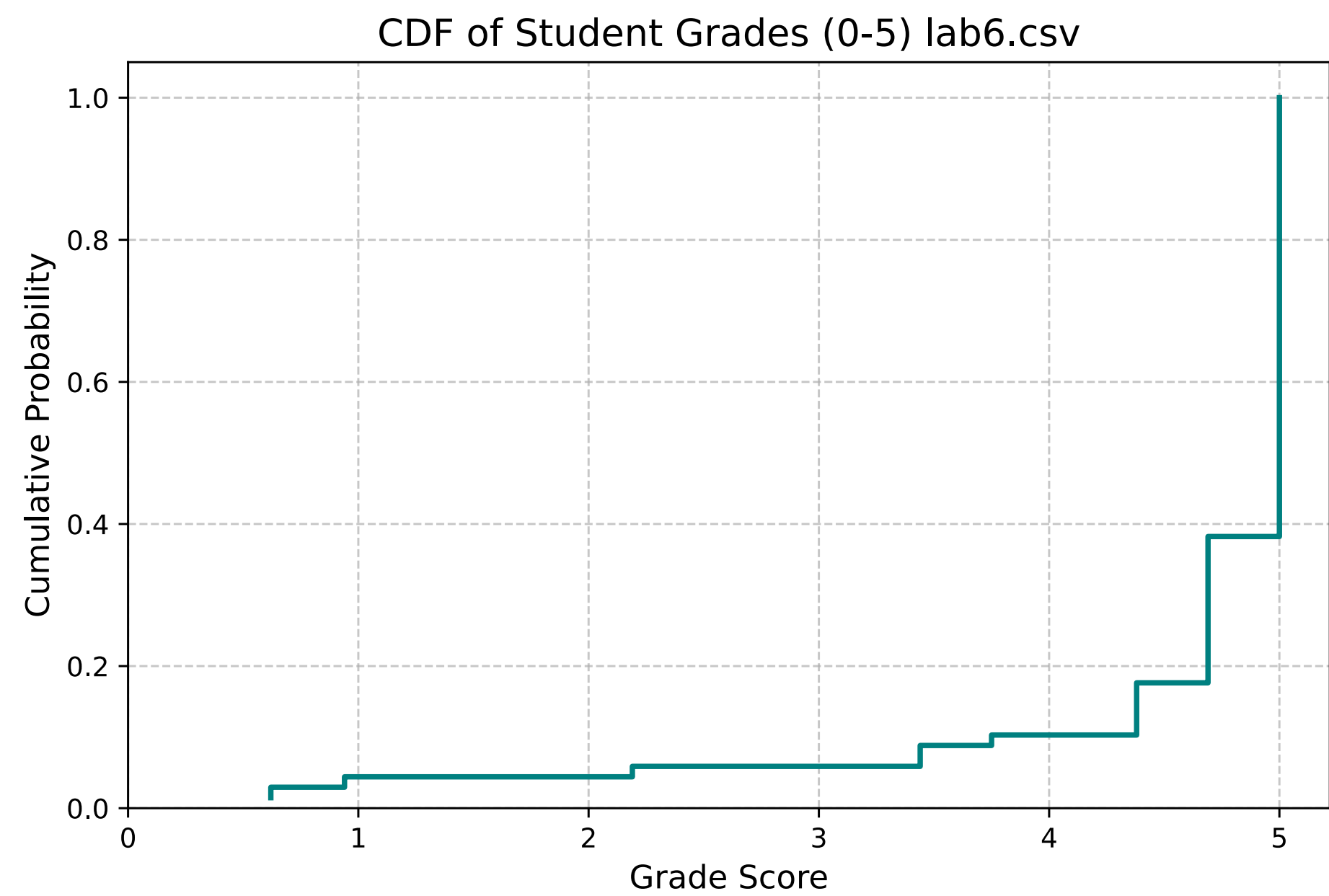


Labs

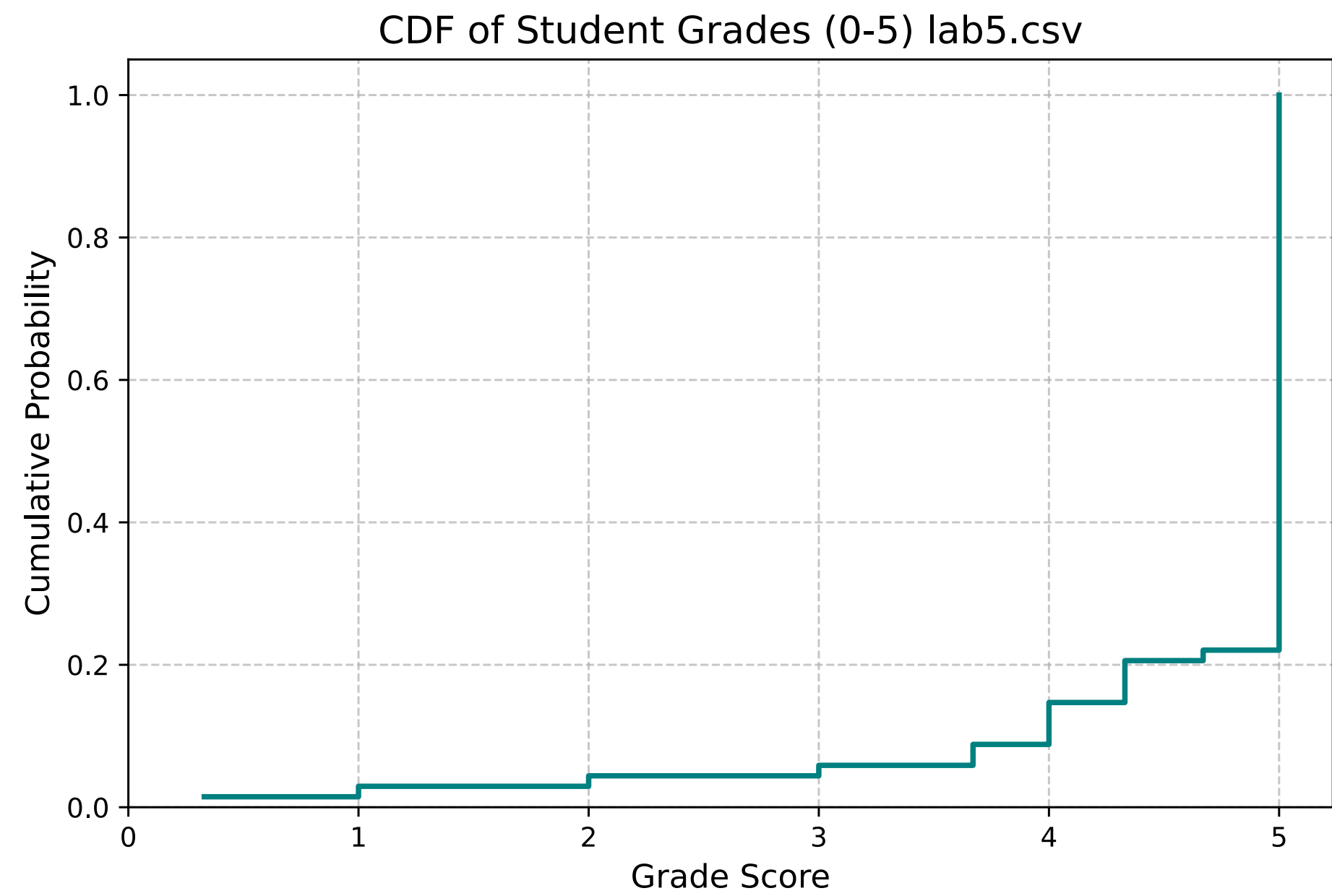
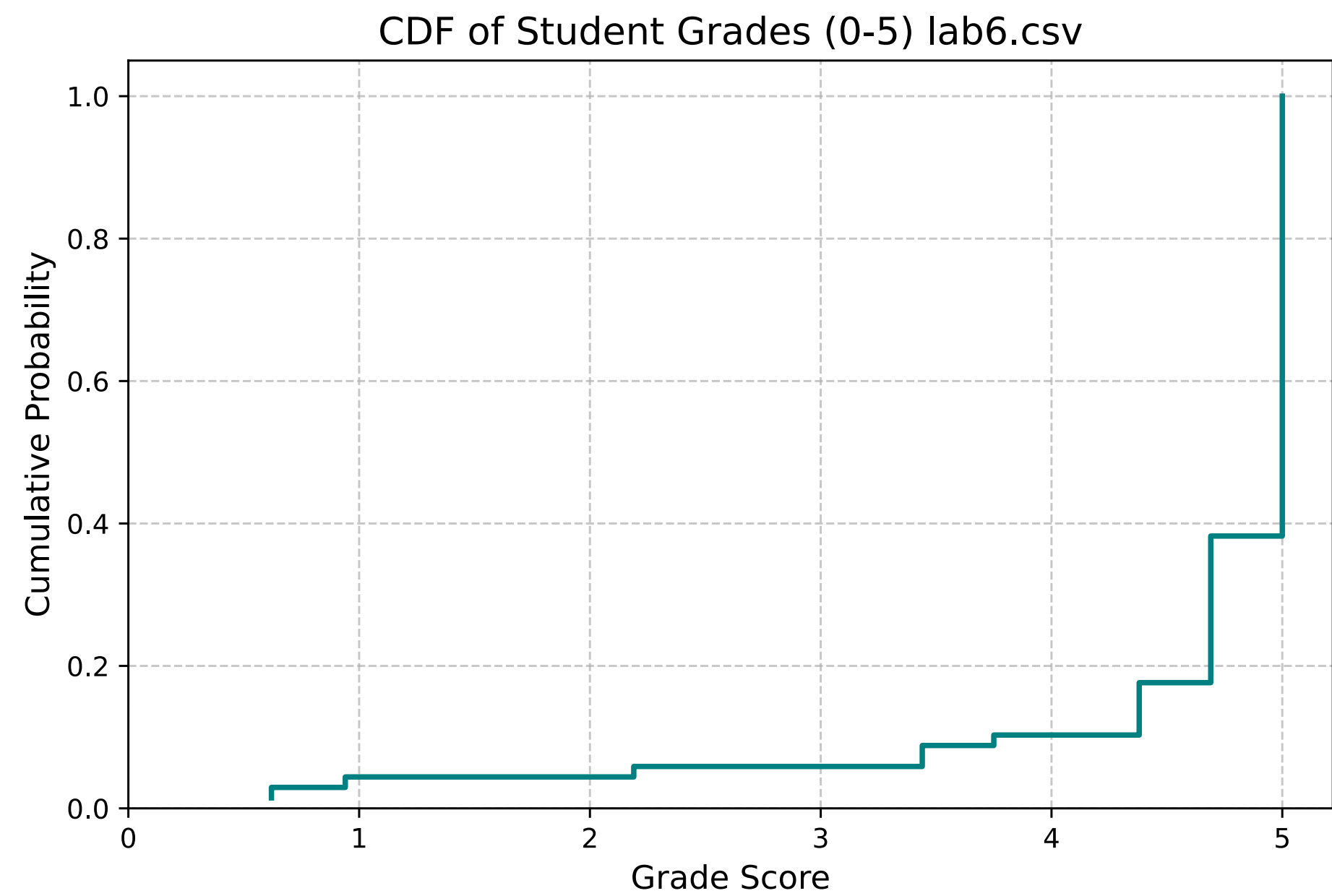
Lab6 was due April 13



Lab5 vs. lab6



Lab5 vs. lab6



Lab5 modifications to image_validate.py

```
#  
# == STUDENTS - START LAB5 MODIFICATIONS ==  
#  
  
validated = is_valid_jpeg(image)  
  
#  
# == STUDENTS - END LAB5 MODIFICATIONS ==  
#
```

Lab6 modifications to image_validate.py

```
#####  
##### LAB6 - TEXT RECOGNITION WITH AMAZON REKOGNITION #####  
try:  
    # STUDENTS - Get an A - text detection goes here  
    # See:  
    # - https://docs.aws.amazon.com/rekognition/latest/dg/text-detection.html  
    # - https://docs.aws.amazon.com/rekognition/latest/dg/text-detecting-text-procedure.html  
    # OLD:  
    # detected_text = ""  
  
    # NEW:  
    response = rekognition_client.detect_text( Image={"Bytes": image} )  
    detected_text = response.get("TextDetections", [])  
  
    # == STUDENTS - END LAB6 MODIFICATIONS ==  
    app.logger.info("detected_text_json=%s",detected_text)  
  
except BotoCoreError as e:  
    detected_text = []  
    app.logger.error("text rekognition error: %s",e)  
#####
```


Lab7 – the MEMENTO or the ESP32-S3-EYE

You can do Lab7 with either the MEMENTO or the ESP32-S3-EYE



Don't delay!

You may find it *challenging* to load circuit python onto your microcontroller.

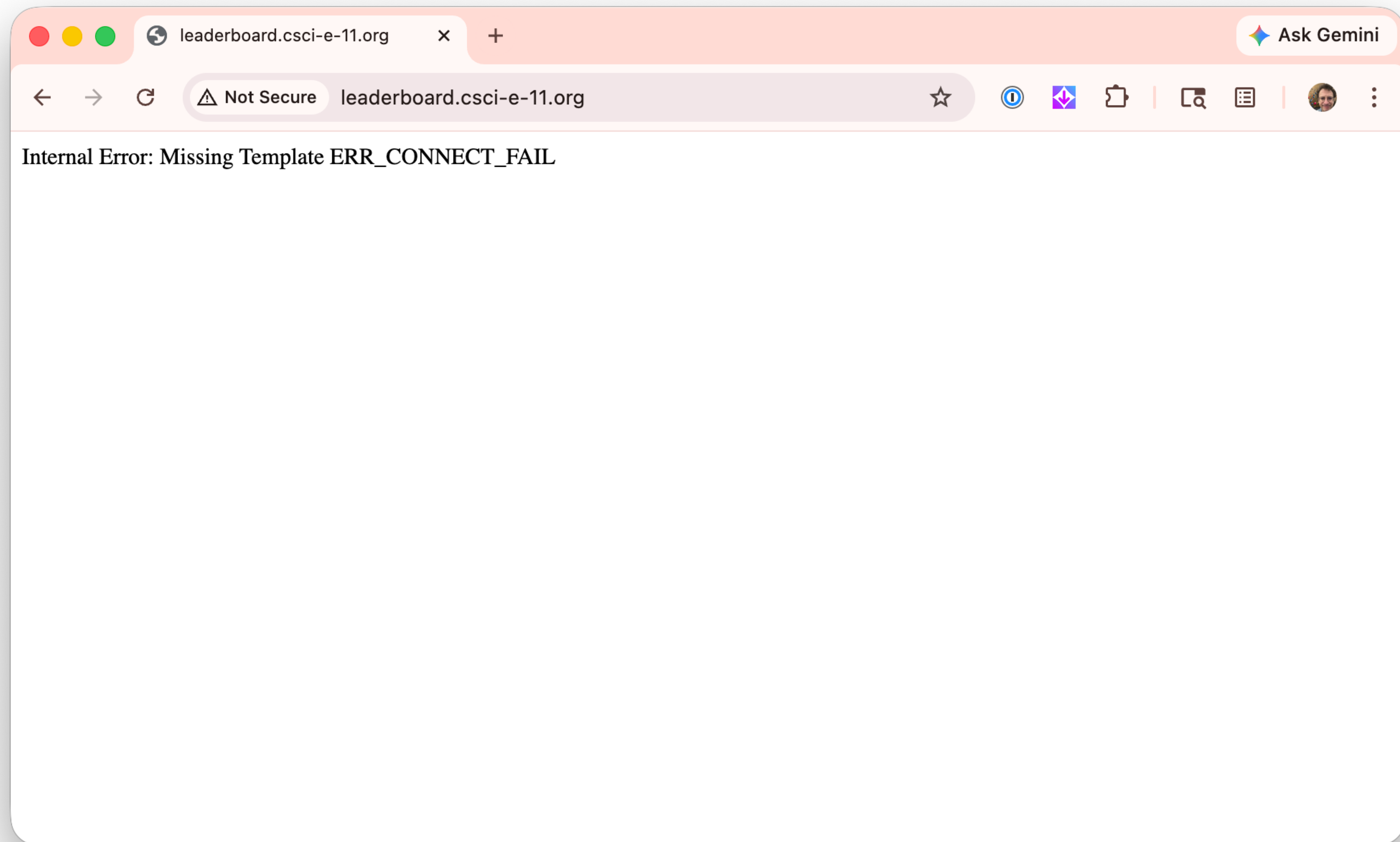
- First try the web-based programmer.
- If that doesn't work, install Python and try the python-based programmer.

You may find it *difficult* to put your microcontroller onto your WiFi network.

- You need to have a simple username/password authentication.
- You cannot use "captive portal"
- It may not work with WPA3 in enterprise authentication mode.
- It will not work if you require a PKI certificate

So it won't work on Harvard WiFi!

Sometimes the leaderboard may appear to not work!



Always make sure you are connecting on https:// and not http://

★ Leaderboard

Ask Gemini

← → ↻ 📄 leaderboard.csci-e-11.org ☆ ⓘ ⚡ 📁 🔍 📄 👤 ⋮

Leaderboard

My name: **BUSTLING VILLAGE**

Status: **Registered.**

Active Players

Name ▲	First Seen ▲	Last Seen ▲	IP Address ▲	User Agent ▲
AMUSING DAD	4/14/2026, 8:18:03 AM	4/14/2026, 8:19:14 AM	137.83.22.241	Mozilla/5.0 (Macintosh; In...
BUSTLING VILLAGE	4/14/2026, 8:19:20 AM	4/14/2026, 8:19:20 AM	137.83.22.241	Mozilla/5.0 (Macintosh; In...

Inactive Players

Name ▲	First Seen ▲	Last Seen ▲	IP Address ▲	User Agent ▲
MYSTERIOUS INSECT	3/27/2026, 11:35:59 AM	3/27/2026, 11:38:45 AM	72.83.246.183	Adafruit CircuitPython
UPBEAT PITCH	3/27/2026, 11:38:52 AM	3/27/2026, 11:39:10 AM	72.83.246.183	Adafruit CircuitPython
SLEEK ORGANIZATION	3/27/2026, 11:39:14 AM	3/27/2026, 11:40:13 AM	72.83.246.183	Adafruit CircuitPython
HARMONIOUS GIFT	3/27/2026, 11:39:56 AM	3/27/2026, 11:40:16 AM	216.183.125.149	Mozilla/5.0 (Macintosh; In...

Remember — if you don't have a microcontroller, you can run the linux client.

It's already on your EC2 Instance!

Harvard-CSCI-E-11 / spring26

Type ↵ to search

<> Code

Issues 28

Pull requests

Agents

Discussions

Actions

Projects

Security and quality 10

Insights

Settings

Files

main

Go to file

> .githubhooks

> .github

> doc

> etc

> lab1

> lab2

> lab3

> lab4

> lab5

> lab6

lab7_linux

lab7_memento

lab8

lab8_linux

lab8_memento

lab_common

spring26 / lab7_linux

Add file

sim song cleaned up 19b08e3 · 4 months ago History

Name	Last commit message	Last commit date
..		
Makefile	cleaned up	4 months ago
linux_client.py	cleaned up	4 months ago
poetry.lock	cleaned up	4 months ago
pyproject.toml	cleaned up	4 months ago

https://github.com/Harvard-CSCI-E-11/spring26/security

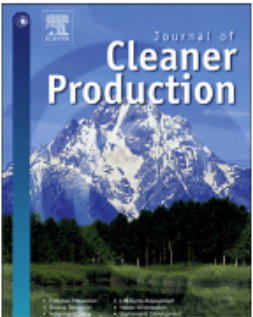
Next week’s reading: Nizetic, et al.



Contents lists available at [ScienceDirect](#)

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro



Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future



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ABSTRACT

The rapid development and implementation of smart and IoT (Internet of Things) based technologies have allowed for various possibilities in technological advancements for different aspects of life. The main goal of IoT technologies is to simplify processes in different fields, to ensure a better efficiency of systems (technologies or specific processes) and finally to improve life quality. Sustainability has become a key issue for population where the dynamic development of IoT technologies is bringing different useful benefits, but this fast development must be carefully monitored and evaluated from an environmental point of view to limit the presence of harmful impacts and ensure the smart utilization of limited global resources. Significant research efforts are needed in the previous sense to carefully investigate the pros and cons of IoT technologies. This review editorial is partially directed on the research contributions presented at the 4th International Conference on Smart and Sustainable Technologies held in Split and Bol, Croatia, in 2019 (SpliTech 2019) as well as on recent findings from literature. The SpliTech2019 conference was a valuable event that successfully linked different engineering professions, industrial experts and finally researchers from academia. The focus of the conference was directed towards key conference tracks such as Smart City, Energy/Environment, e-Health and Engineering Modelling. The research presented and discussed at the SpliTech2019 conference helped to understand the complex and intertwined effects of IoT technologies on societies and their potential effects on sustainability in general. Various application areas of IoT technologies were discussed as well as the progress made. Four main topical areas were discussed in the herein editorial, i.e. latest advancements in the further fields: (i) IoT technologies in Sustainable Energy and Environment, (ii) IoT enabled Smart City, (iii) E-health – Ambient assisted living systems (iv) IoT technologies in Transportation and Low Carbon Products. The main outcomes of the review introductory article contributed to the better understanding of current technological progress in IoT application areas as well as the environmental implications linked with the increased application of IoT products.

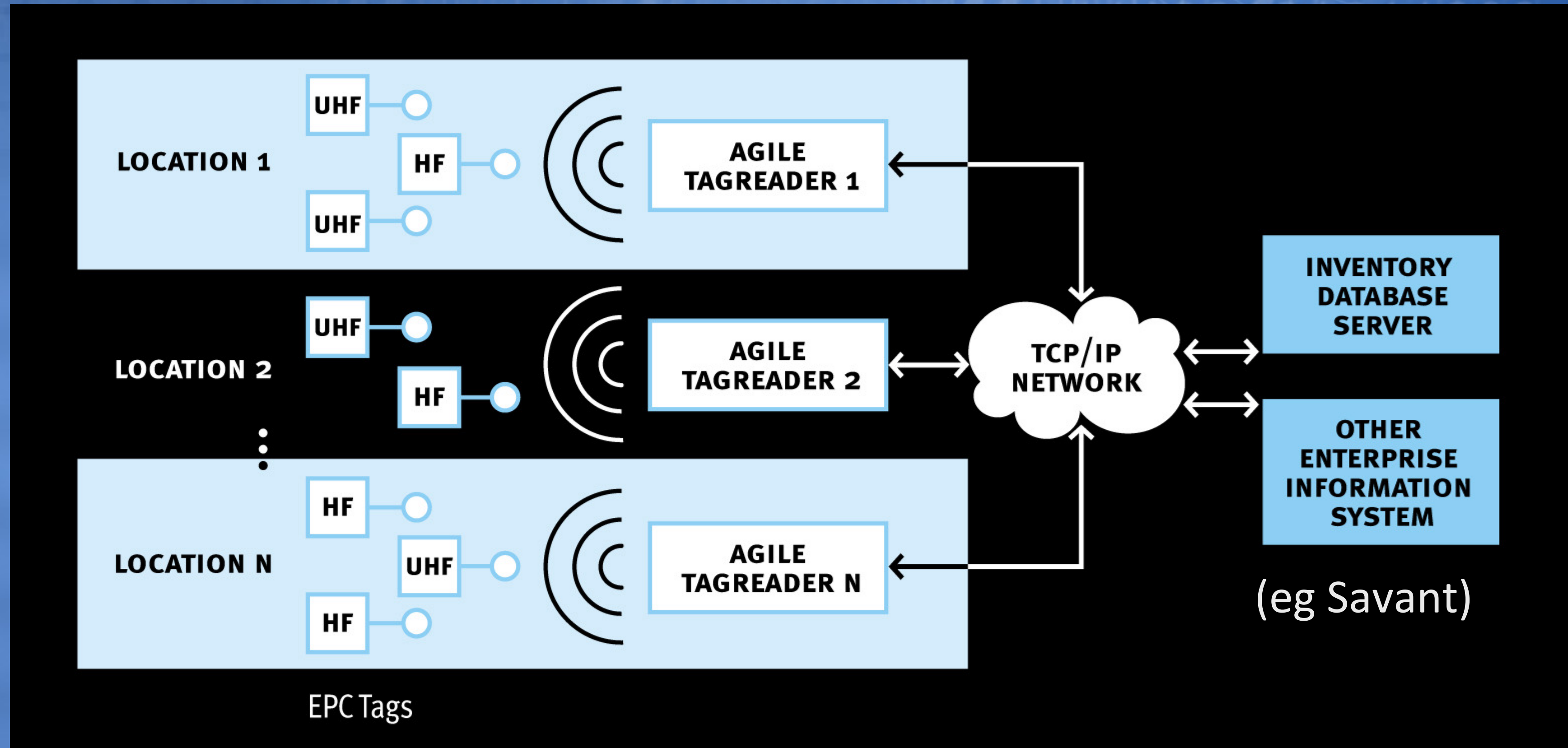
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For Next Week

- Read Nizetic
 - Comment and respond on Perusall
 - Take the reading quiz
 - Participate in Ed Board discussion
 - Start Lab 7 (due April 27)
 - If necessary, get an extension on your taxes (but you still have to pay by 4/15!)
 - Enjoy the weather!
-



Elements of an RFID system



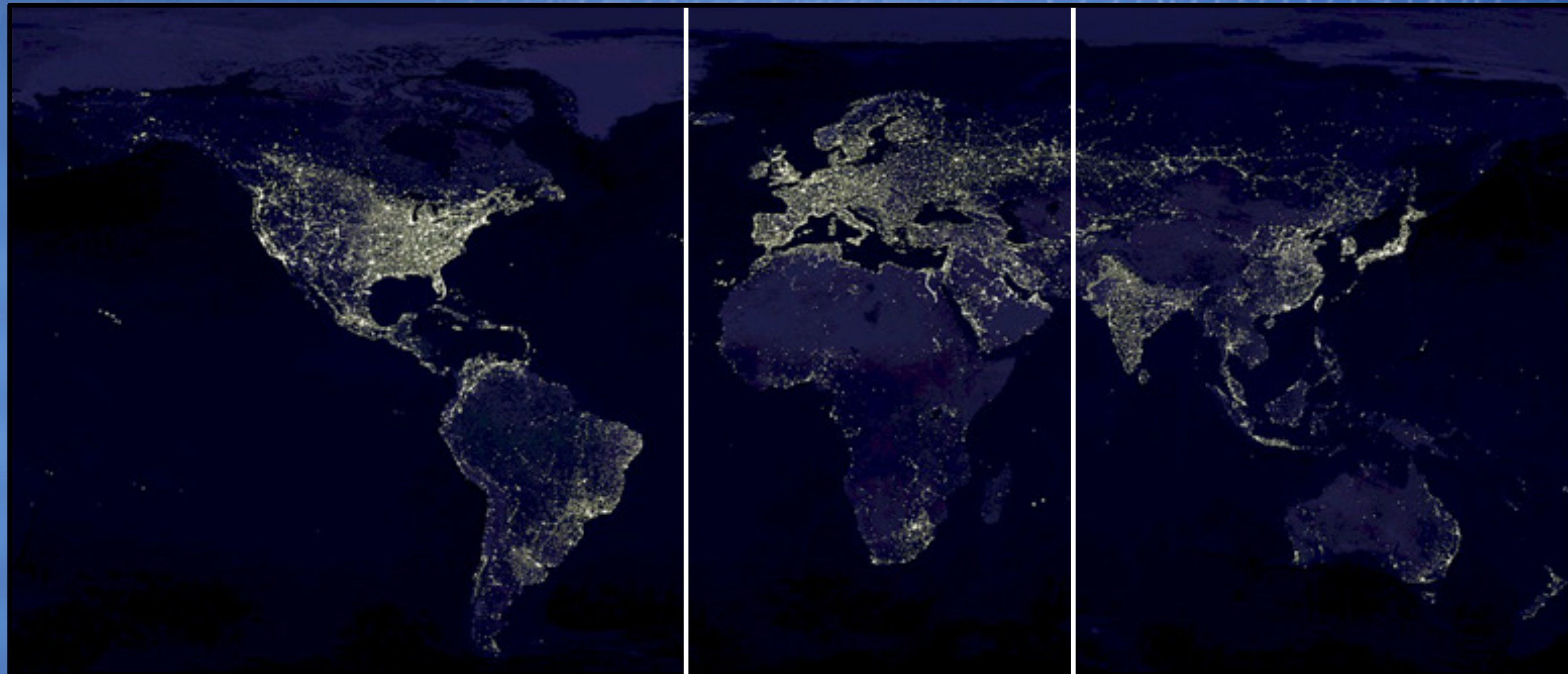
Four main elements: Tags, Readers, Antennas, and Network Systems

RF system variables

1. Choice of operating frequency
2. Tag IC, tag antenna design
3. Reader, reader antenna design
4. Proximate materials
5. Sources of external interference



Major RFID markets by frequency



US, Canada

125KHz

13.56MHz

902-928MHz

EU Countries

125KHz

13.56MHz

868-870MHz

Japan

125KHz

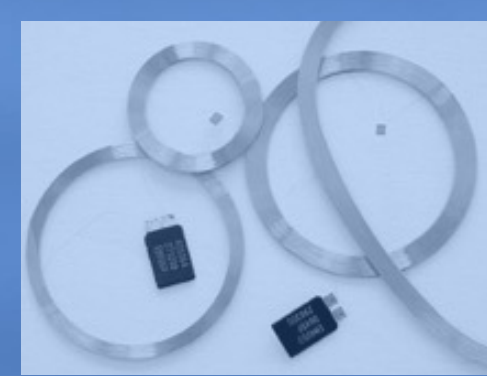
13.56MHz

950-956MHz

RFID tags at different frequencies

125 KHz

TI
Philips
Others



13.56 MHz

Tagsys
Philips
TI
Microchip
Others



915 MHz

Intermec
SCS
Matrics
Alien
Philips
TI

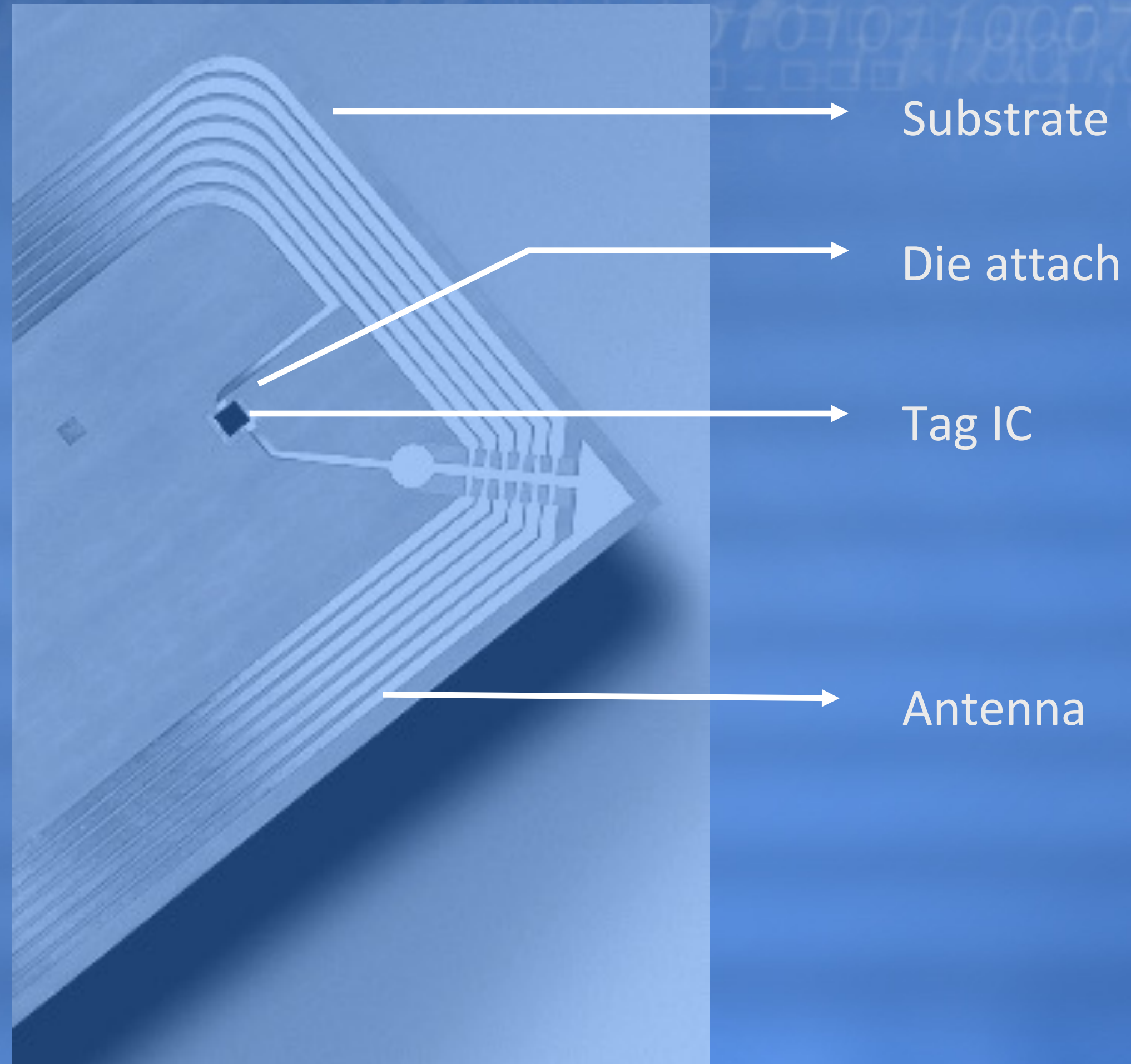


2.4 GHz

Intermec
SCS
Hitachi



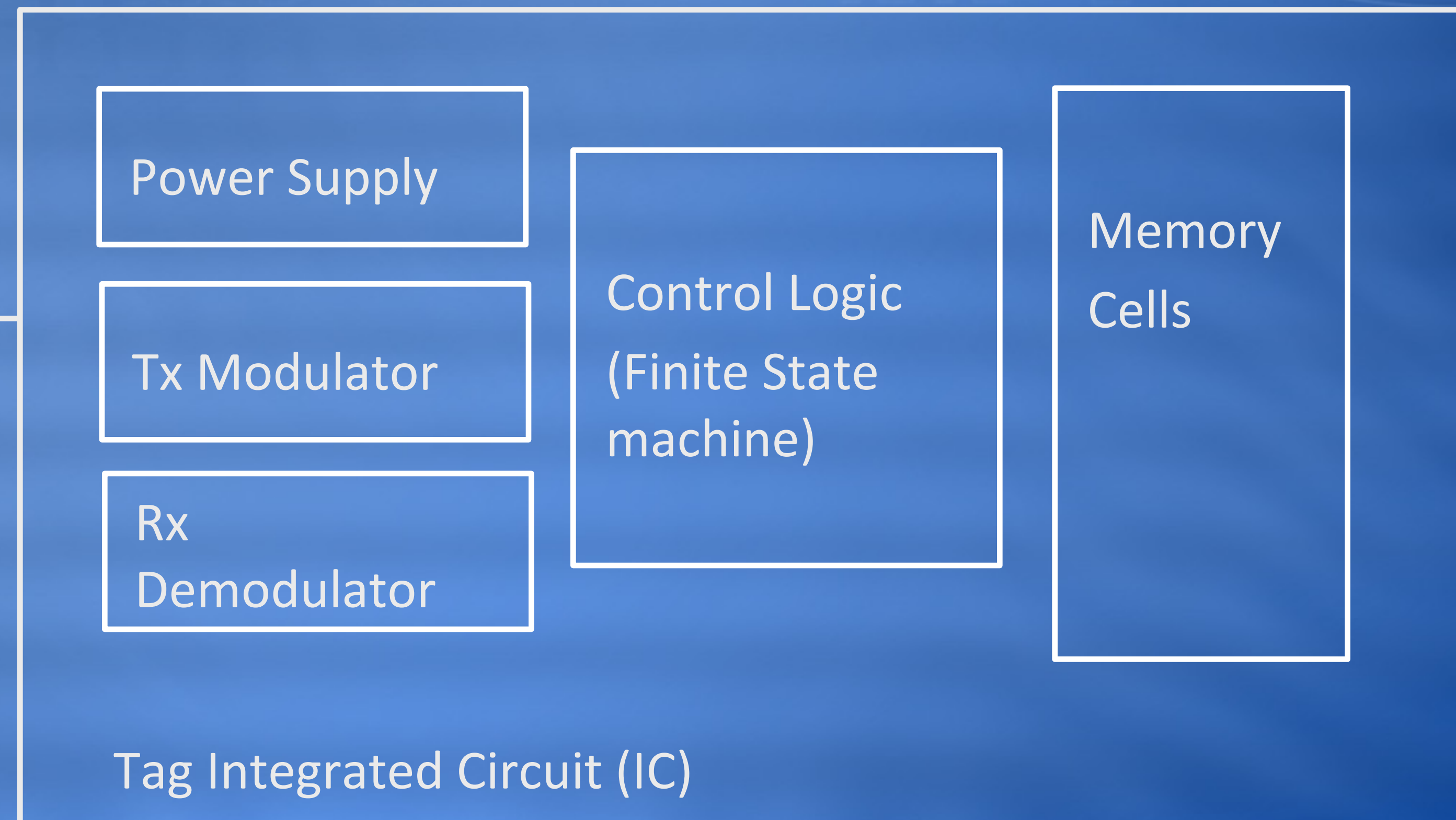
Tag anatomy





Tag block diagram

Antenna





What does a reader do?

- Primary functions:
 - Remotely power tags
 - Establish a bidirectional data link
 - Inventory tags, filter results
 - Communicate with networked server(s)





Reader anatomy

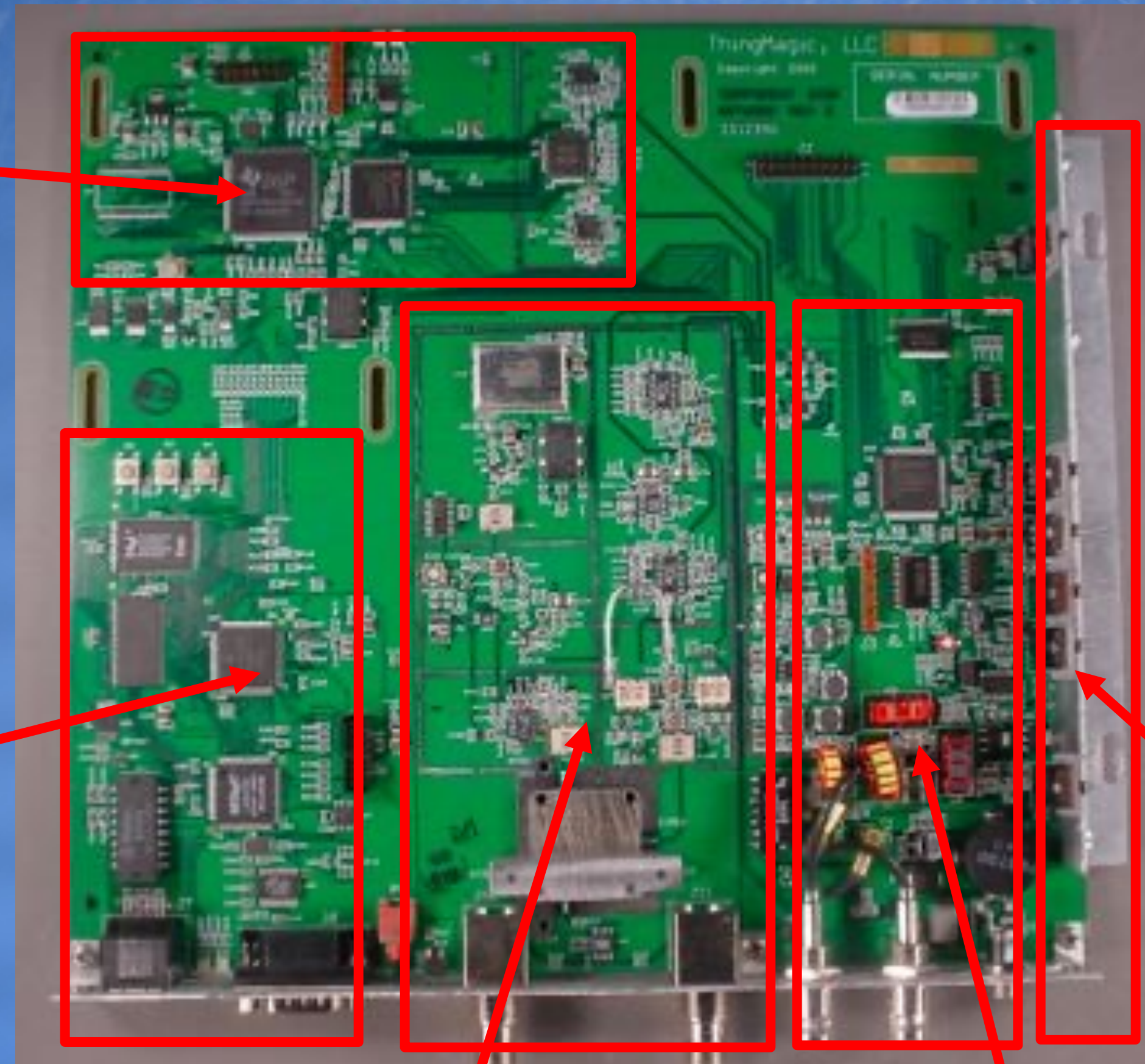
Digital Signal
Processor
(DSP)

Network
Processor

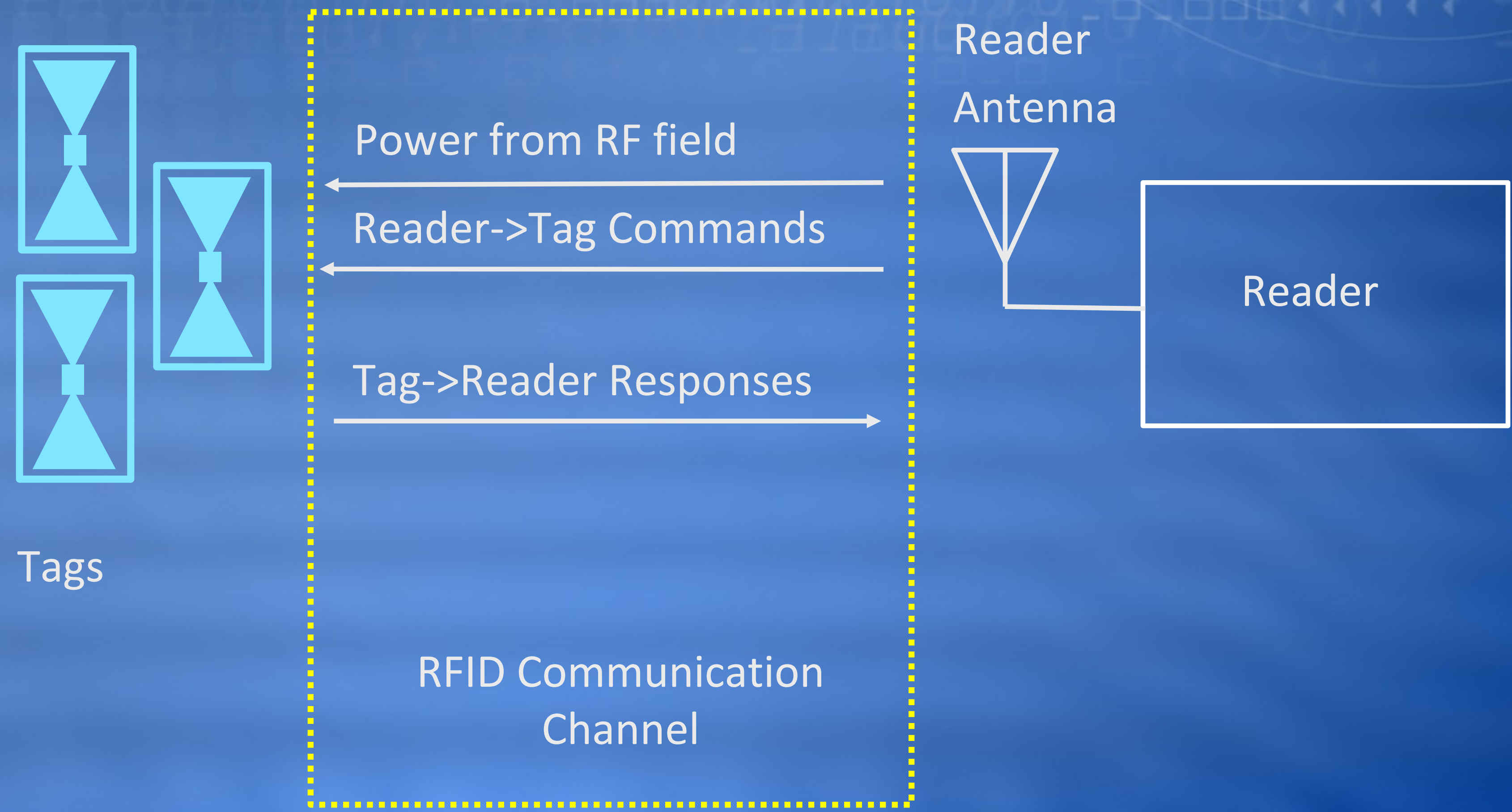
Power
Supply

915MHz
Radio

13.56MHz
Radio



A passive RFID communication model

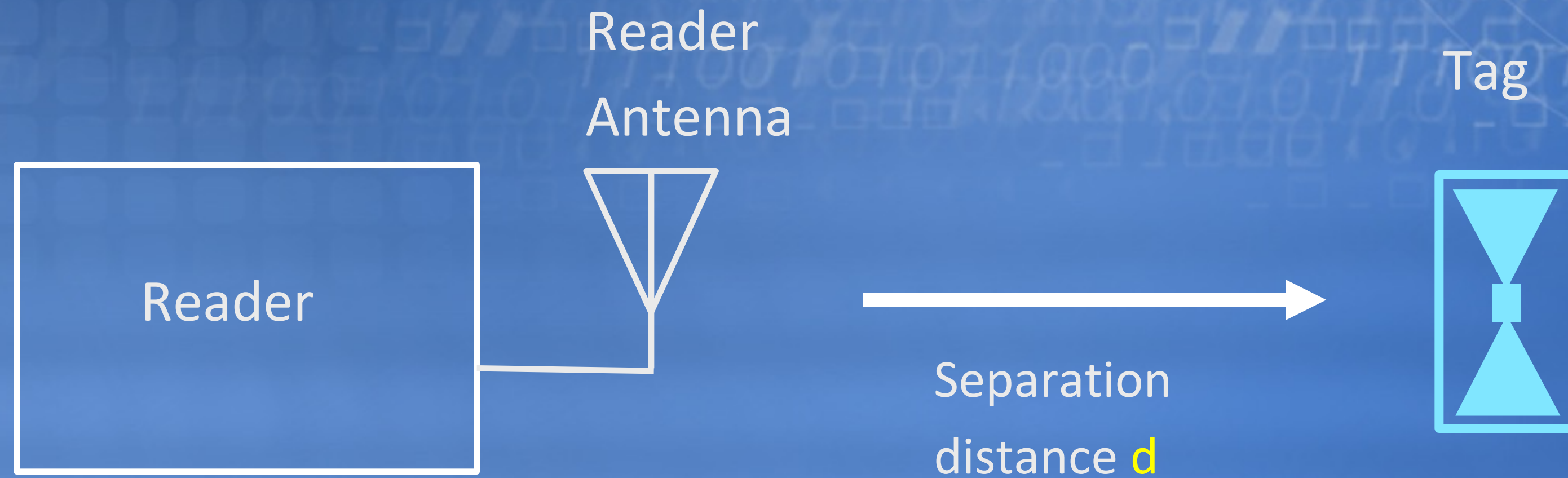




Limiting factors for passive RFID

1. Reader transmitter power P_r (Gov't. limited)
2. Reader receiver sensitivity S_r
3. Reader antenna gain G_r (Gov't. limited)
4. Tag antenna gain G_t (Size limited)
5. Power required at tag P_t (Silicon process limited)
6. Tag modulator efficiency E_t

Reader->Tag power transfer



Q: If a reader transmits P_r watts, how much power P_t does the tag receive at a separation distance d ?

A: It depends-

UHF (915MHz) : Far field propagation : $P_t \propto 1/d^2$

HF (13.56MHz) : Inductive coupling : $P_t \propto 1/d^6$



Typical UHF system parameters

- Reader Transmit Power $P_r = 30\text{dBm}$ (1 Watt)
- Reader Receiver Sensitivity $S_r = -80\text{dBm}$ (10^{-11} Watts)
- Reader Antenna Gain $G_r = 6\text{dBi}$
- Tag Power Requirement $P_t = -10\text{dBm}$ (100 microwatts)
- Tag Antenna Gain $G_t = 1\text{dBi}$
- Tag Backscatter Efficiency $E_t = -20\text{dB}$
- System operating wavelength $\lambda = 33\text{cm}$ (915MHz)



Conclusions

- There are **serious practical limitations** to passive RFID read range.
- It is **not practical** to read a passive UHF RFID tag from Earth orbit.
- Improvements to tag IC design will yield commercially helpful, but probably **privacy-insignificant** increase in read range.
- UHF RFID signals are **easily shielded** by common materials (aluminum foil, antistatic bags, or your hands).