Why is the Internet of Things (IoT) Definition-less?

Foundations of the IoT

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Question

Where is *the* Definition for IoT?

Wikipedia's Got One

*The **Internet of Things** (**IoT**) is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure.*

IEEE's IoT Initiative Has One

- from the Initiative's White Paper

- **Small environment scenario:**
  - It's a network that connects uniquely identifiable *"Things"* to the internet.
  - The "Things" have sensing/actuation and potential programmability capability.
  - Information about the "Thing" can be collected.
  - The state of the "Thing" can be changed.
  - From anywhere, at anytime, by anything
- **Large environment scenario:**
  - A self-configuring and adaptive complex network that interconnects *"things"* to the internet through the use of interoperable communication protocol.

InterNational Committee for Information Technology Standards (INCITS) Has One

JTC 1 N 12651 - Text for NWIP ballot on Information technology — Internet of Things — Definition and Vocabulary.pdf modified

Real Answer

Nowhere - No simple, usable, universally-accepted, and actionable definition currently exists.

To address this, I opted to start from the *fundamentals*, i.e., the main *ingredients* that define the *behavior* of the IoT. These fundamentals form the foundation of the IoT.

But, *I do not define IoT*.

Opening Statement

A Network of Things (NoT) employs a mixture of sensing, communication, computation.

A Network of Things (NoT) leads to actionable decisions or predictions. Things may be *private* or *public*. Things may be 3rd party or homegrown.

A Network of Things (NoT) is only one example of a distributed computing system.

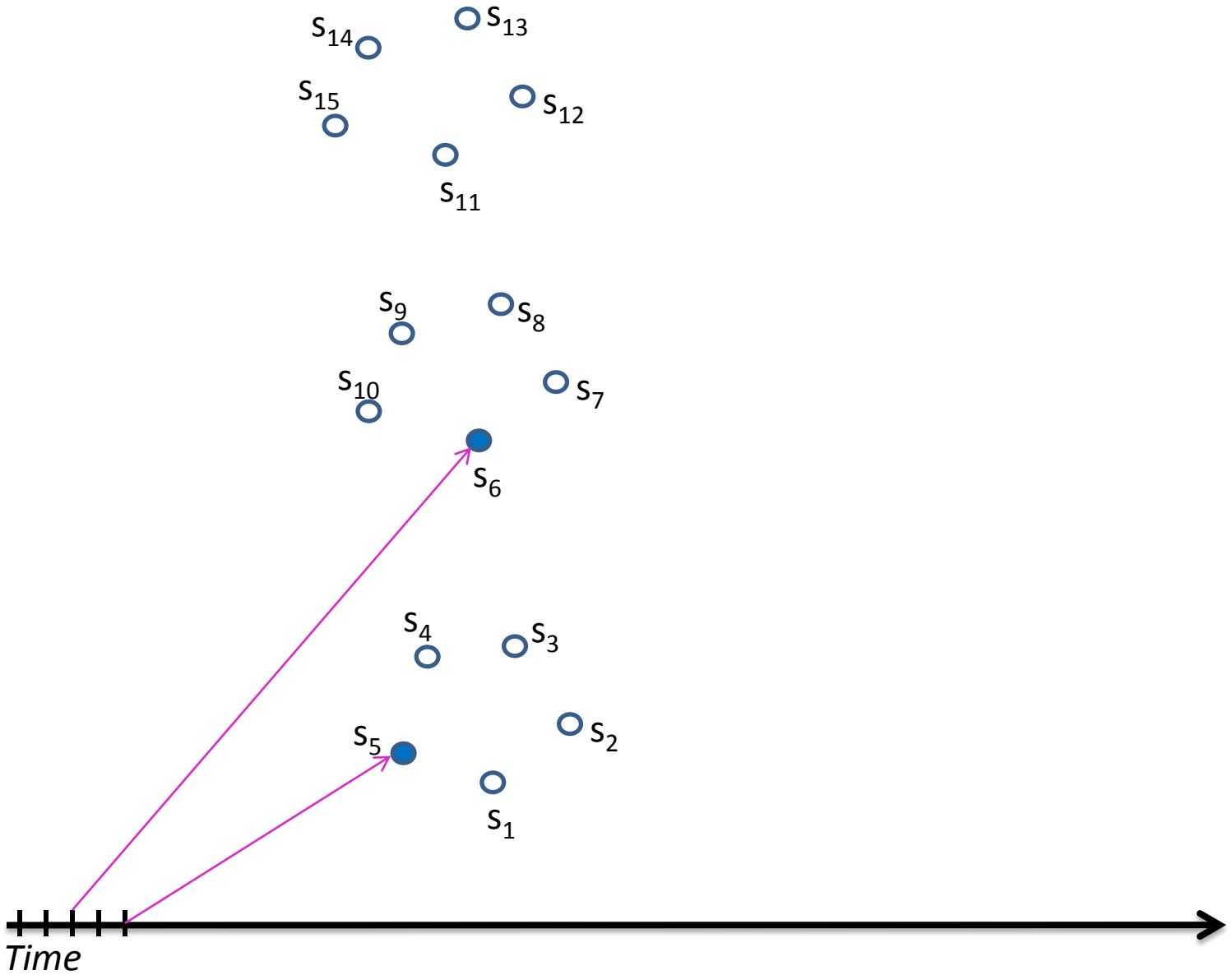
The ‘so-called’ Internet of Things (IoT) is one type of a NoT – others exist.

IoT *vs*. NoT

The terms “IoT” and “NoT” are interchangeable - the relationship between NoT and IoT is simple, yet subtle. IoT is an *instantiation* of a network of things, and in particular, IoT has its ‘things’ tethered to the Internet. A different type of NoT, on the other hand, could be a Local Area Network (LAN) of ‘things’ with no access to any ‘thing’ tethered to the Internet. Social media networks, sensor networks, and industrial internet, are variants of NoTs. This differentiation in terminology provides ease in separating out use cases from varying vertical and quality domains (e.g., transportation, medical, financial, agricultural, safety-critical, security-critical, performance-critical, high assurance, to name a few). That proves invaluable, as there is no single static IoT. IoT remains *definition-less*. This is contrary to current discourse.

The Foundation: Eight Primitives

1. Sensor - an electronic utility that digitally measures physical properties such as temperature, acceleration, weight, sound, etc. Cameras and microphones are also treated as sensors
2. Snapshot (time) - an instant in *time*. Because a network of things is a distributed computing system, different events, data transfers, and computations occur at different times. Therefore it is necessary to consider *time* as a primitive.
3. Cluster - a grouping of sensors that can appear and disappear instantaneously.
4. Aggregator - a software implementation based on mathematical function(s) that transforms various sensor data into *intermediate* data.
5. Weight - the degree to which a particular sensor's data will impact an aggregator's computation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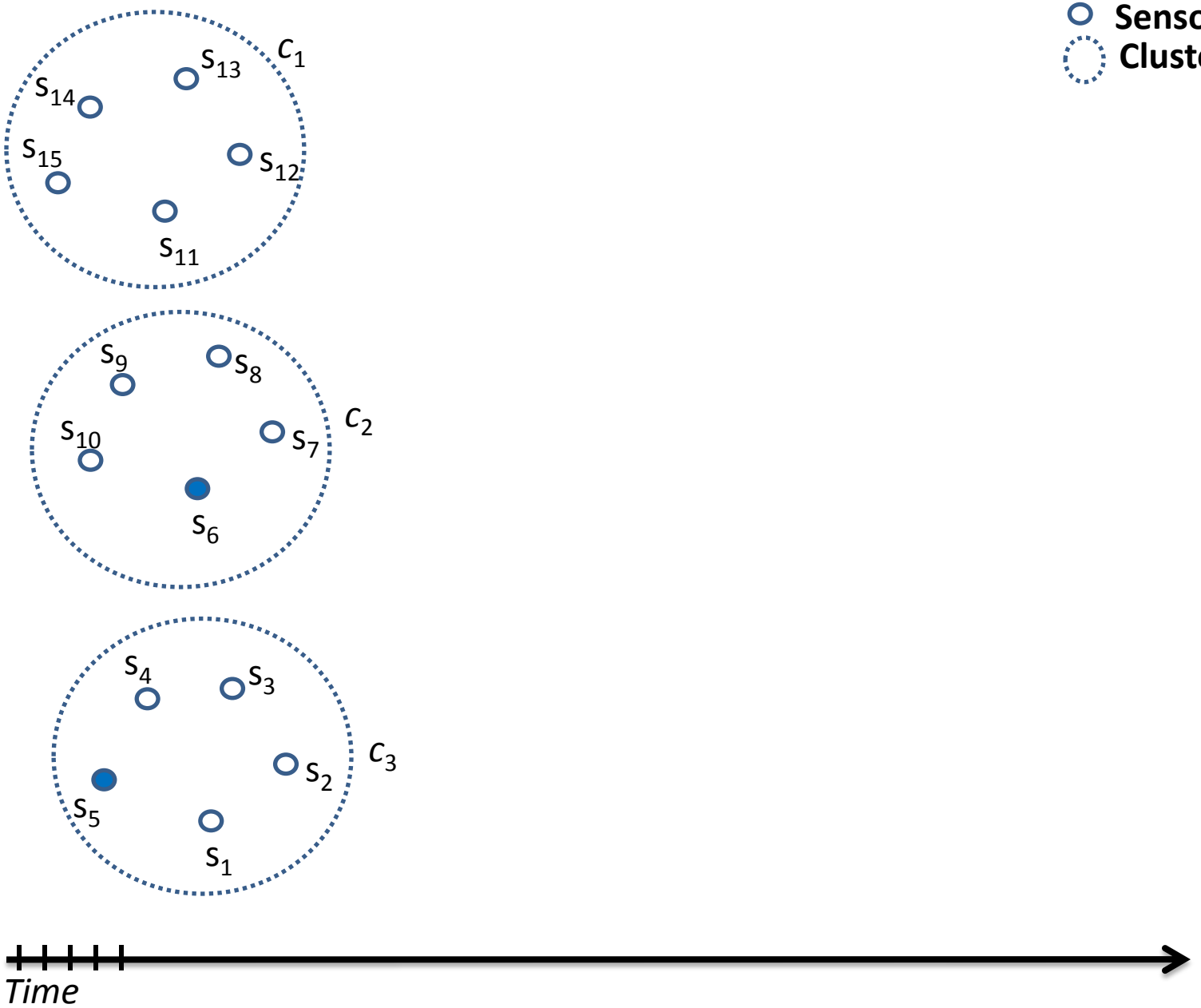
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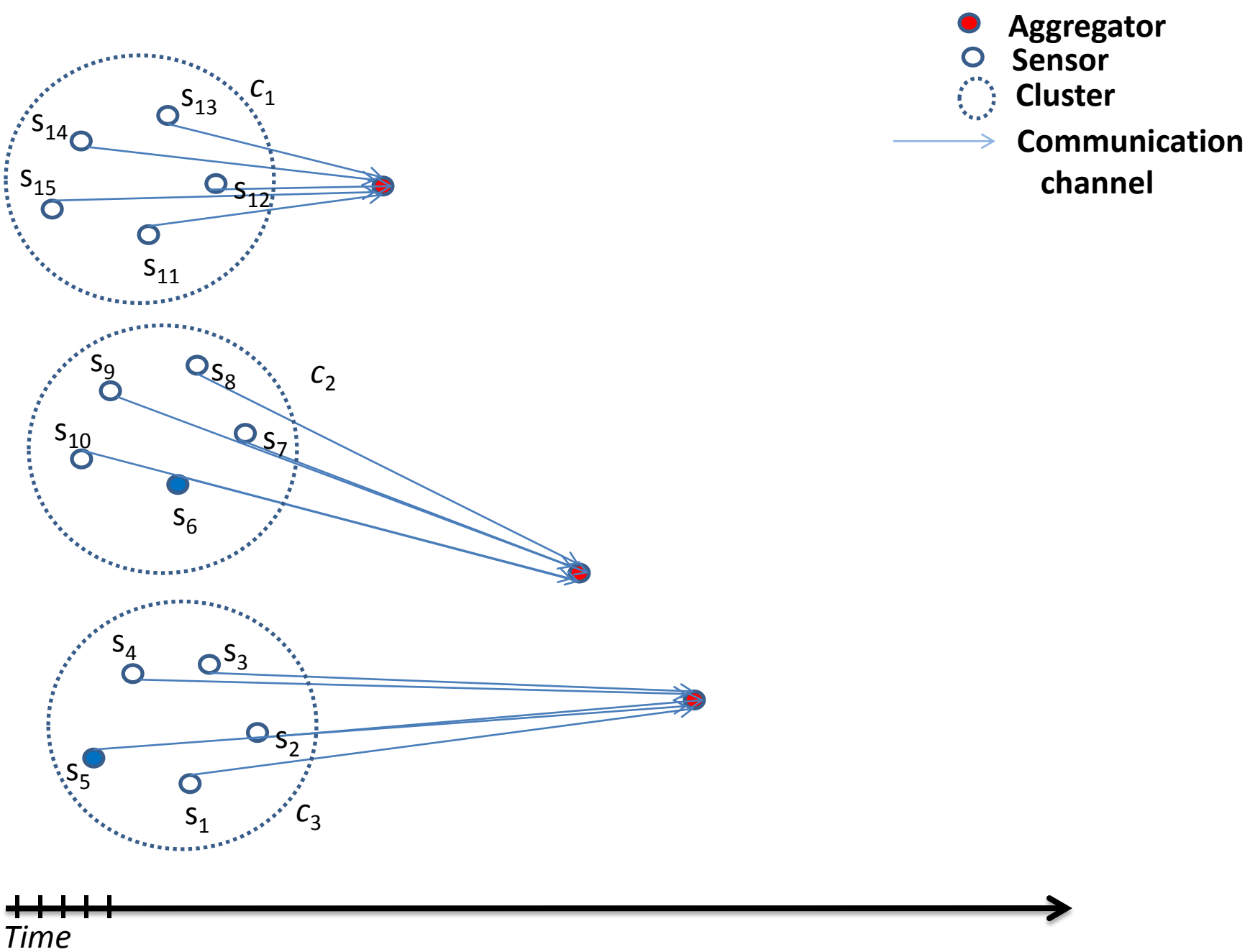
Time

The Foundation: Eight Primitives

6. Communication channel – any medium by which data is transmitted (e.g., physical via USB, wireless, wired, verbal, etc.).
7. *e*Utility - a software or hardware product, or service, that executes processes or feeds data into the overall dataflow of the NoT.
8. Decision trigger - the final executor of data concentrations and any other data needed to satisfy the purpose and requirements of a specific NoT.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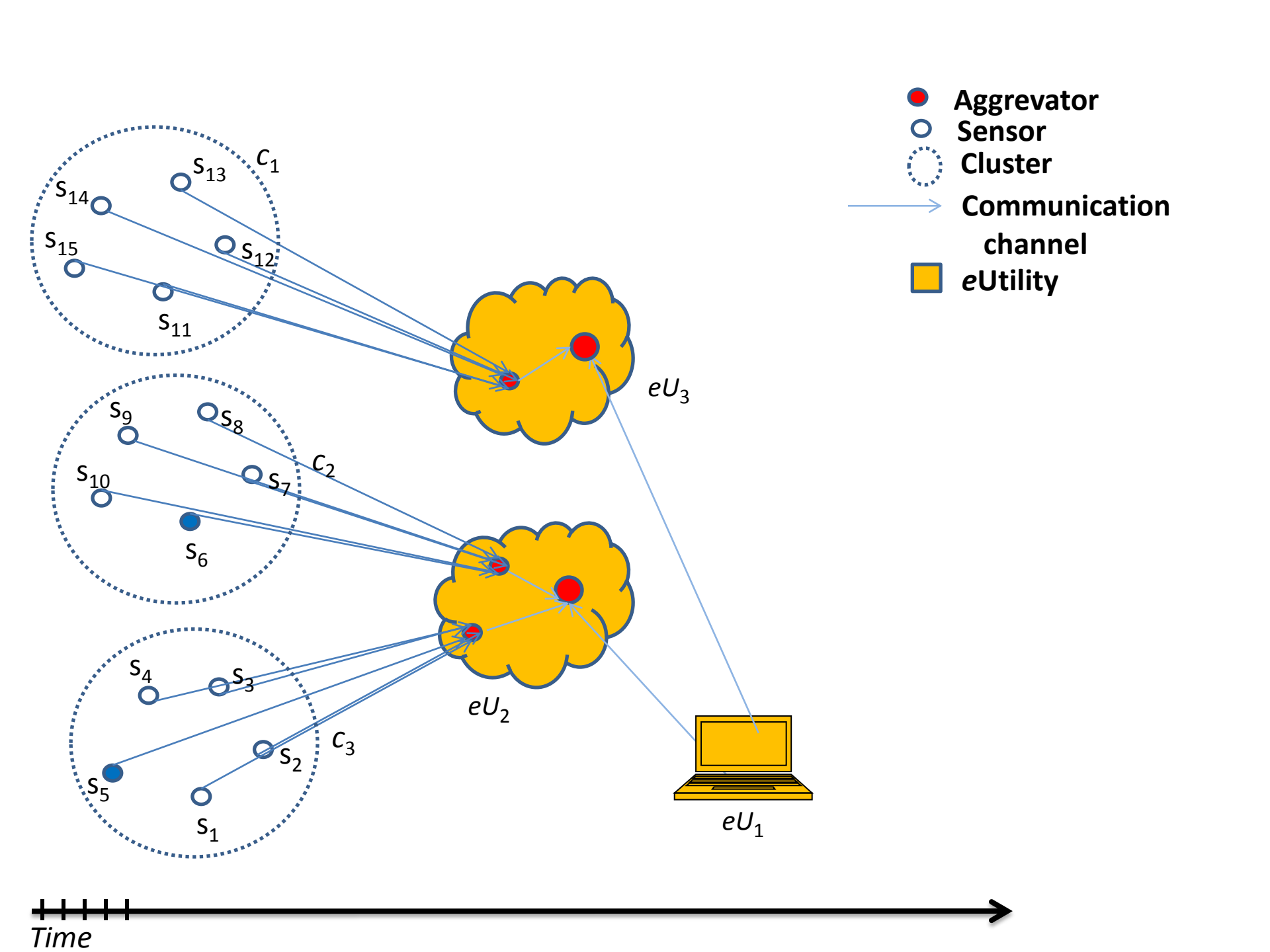
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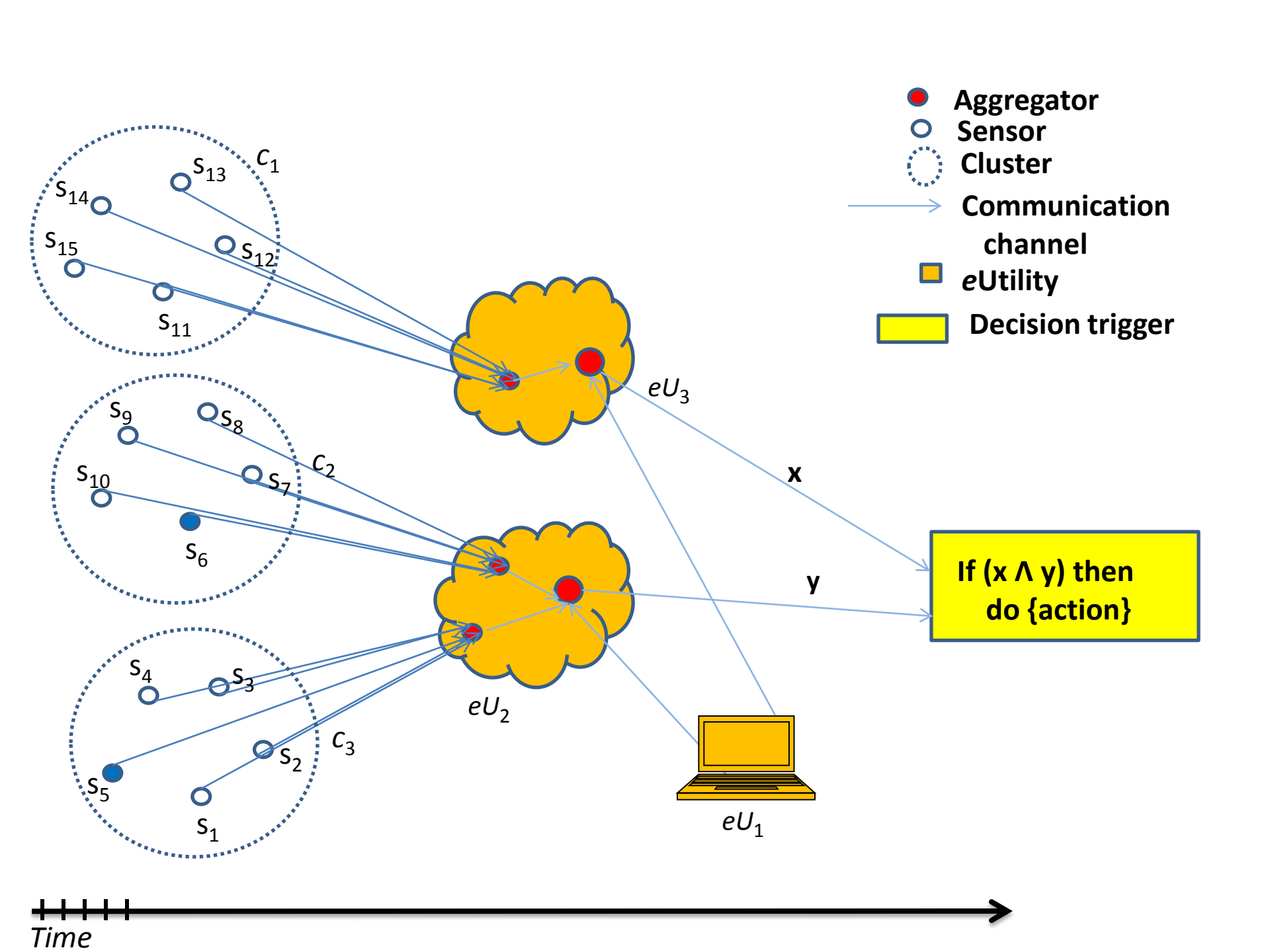
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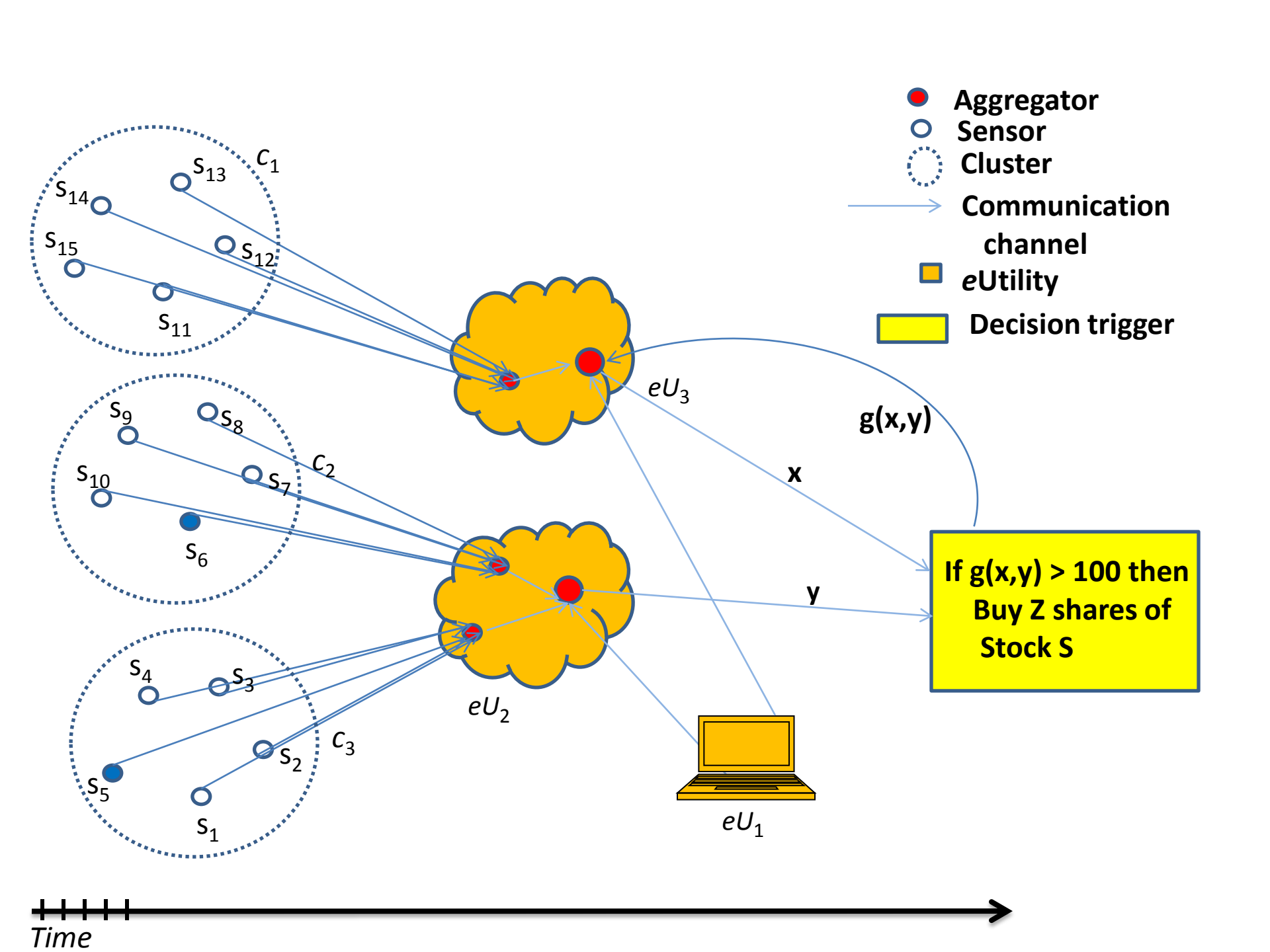
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s_3
eU_2
c_3
s_2
s_5
s_1
eU_1
Time

The Foundation: Six Other Elements

1. **Data** – The flow of information in a NoT's workflow; data may be transferred virtually or by physical means.
2. **Environment** – The universe that all primitives in a private NoT operate in; this is essentially the *operational profile* of a private NoT. An analogy is the various weather profiles that an aircraft operates in or a particular factory setting that a NoT operates in. This may be very difficult to correctly define.
3. **Cost** – The expenses, in terms of time and money, that a specific private NoT incurs in terms of the non-mitigated reliability and security risks, as well as the costs associated with each of the primitives needed to build the private NoT. Cost is an estimation or prediction.
4. **Geographic location –** Physical place where a sensor or *e*Utility operates or was manufactured. Manufacturing location is a supply chain trust issue. Note that the operating location may change over time. Note that a sensor's or *e*Utility's geographic location along with communication channel reliability may affect the ability to move data throughout the workflow in a timely manner. Geographic location determination may sometimes be not possible.
5. **Owner** - Person or Organization that owns a particular sensor, communication channel, aggregator, decision trigger, or *e*Utility. There can be multiple owners for any of these five. Note that owners may have nefarious intentions that affect overall trust. Note further that owners may remain anonymous.
6. **Device_ID** – A unique identifier for a particular sensor, communication channel, aggregator, decision trigger, or *e*Utility. This will typically originate from the originator of the entity, but it could be modified or forged.

The Goal: Composition and *Trust*

Primitive or Actor	Attribute	Pedigree an Issue?	Reliability an Issue?	Security an Issue?
Sensor	Physical	Y	Y	Y
Snapshot (time)	Natural phenomenon	N/A	Y	?
Cluster	Abstraction	N/A	?	?
Aggregator	Virtual	Y	Y	Y
Weight	Variable constant	N/A	Y	?
Communication channel	Virtual or Physical	Y	Y	Y
eUtility	Virtual or Physical	Y	Y	Y
Decision trigger	Virtual	Y	Y	Y
Geographic location	Physical (possibly unknown)	N/A	?	?
Owner	Physical (possibly unknown)	?	N/A	?
Data	Virtual	Y	Y	Y
Environment	Virtual or Physical (possibly unknown)	N/A	Y	Y
Cost	Partially known	N/A	?	?
Device_ID	Virtual	Y	?	Y

Summary

1. It is unlikely a single, usable definition of IoT can be created and agreed upon
2. A common vocabulary is useful to foster dialogue concerning IoT
3. 8 primitives that impact the trustworthiness of NoTs are proposed
4. 6 elements that impact the trustworthiness of NoTs are proposed
5. NoTs are the likely means by which IoT will be delivered
6. IoT is in part a *big data* problem (maybe "overwhelming" is more accurate than "big")
7. The goal is to someday build definitions of IoT, and better address this assertion:

   ***Trust* in some NoT *A,* at some snapshot *X,* is a function of NoT *A*'s assets ϵ {sensor(s), cluster(s), aggregator(s), weight(s), communication channel(s), *e*Utility(s), decision trigger(s)} with respect to the members ϵ {geographic location, owner, data, environment, cost, Device_IDs}, for each asset in the first set, when applicable.**

Further Reading

A publication with all of this information is available free of charge from:

http://dslsrv.gmu.edu/The%20Foundations%20of%20IoT_v2.5.pdf