Università degli Studi
Mediterranea
di Reggio Calabria

New perspectives on interoperability and communication primitives in 5G Internet of Things networks

Antonio Iera

Before we start...

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cnit consorzio nazionale interuniversitario per le telecomunicazioni

Summary

- Main Issues in 5G–IoT scenarios
- Enabling technologies
- Global system interoperability
- Sociocast: a new network primitive
- Implementation issues
- Future research directions

5G-IoT landscape

- Population of massively connected devices, different from the current one
- The lion's share taken by sensors & actuators and by everyday augmented objects typical of the Internet of Things (IoT)
- Virtualized and programmable network functions and resources
- Delivery of new and increasingly sophisticated services to heterogeneous groups of (mobile) users

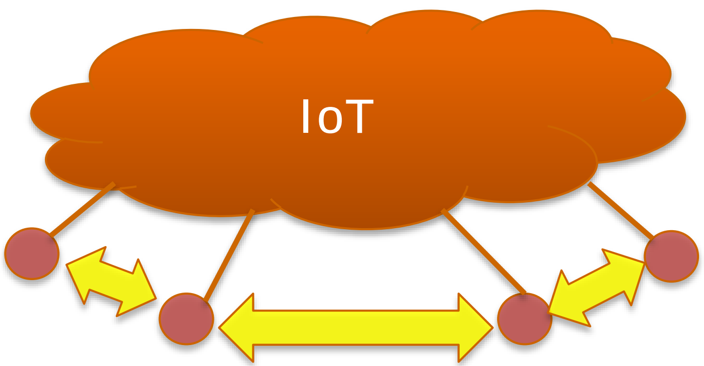
Issues related to the IoT "structure" in 5G

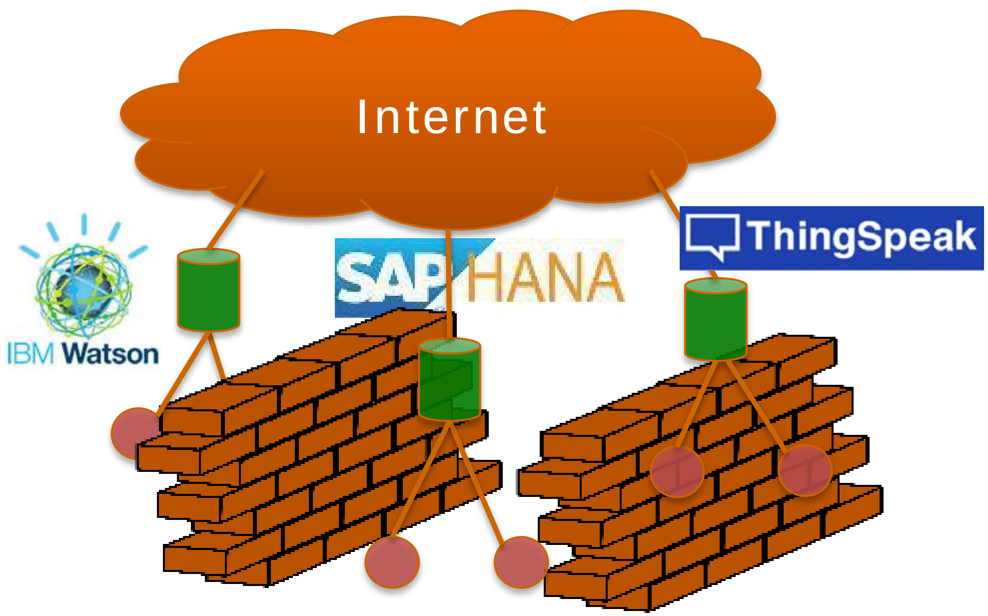
What it was supposed to be:

"A worldwide network of interconnected objects, uniquely addressable based on standard communication protocols"

What it currently is:

"A bunch of platforms in which smart things are not uniquely addressable and interact with their servers only, possibly, using proprietary semantics and protocols"





Causes and effects

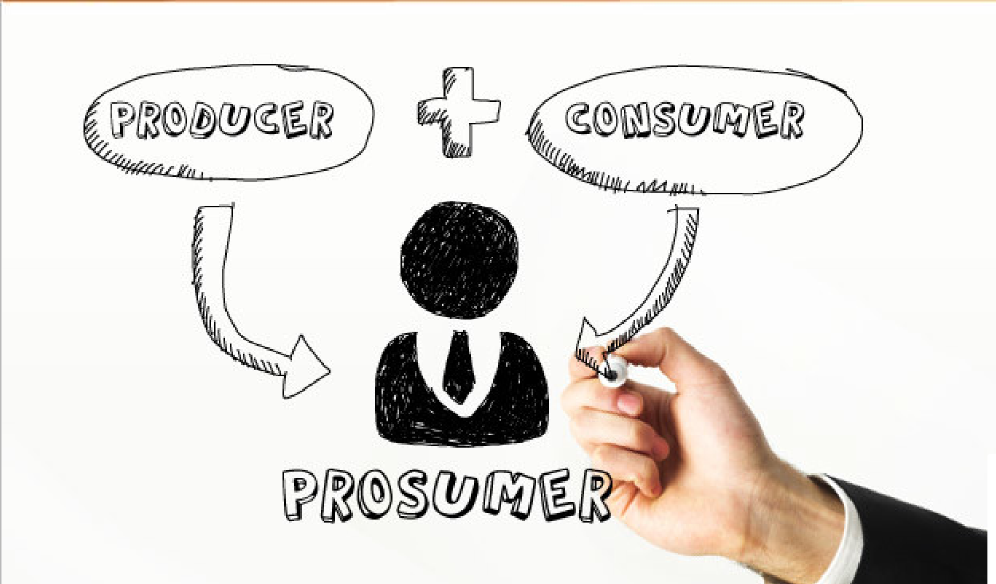
Causes

- Slow standardization process
  - IT companies could not wait for the end of the "*war of IoT protocols*"
- Well established business models
- Simplicity granted by a centralized database

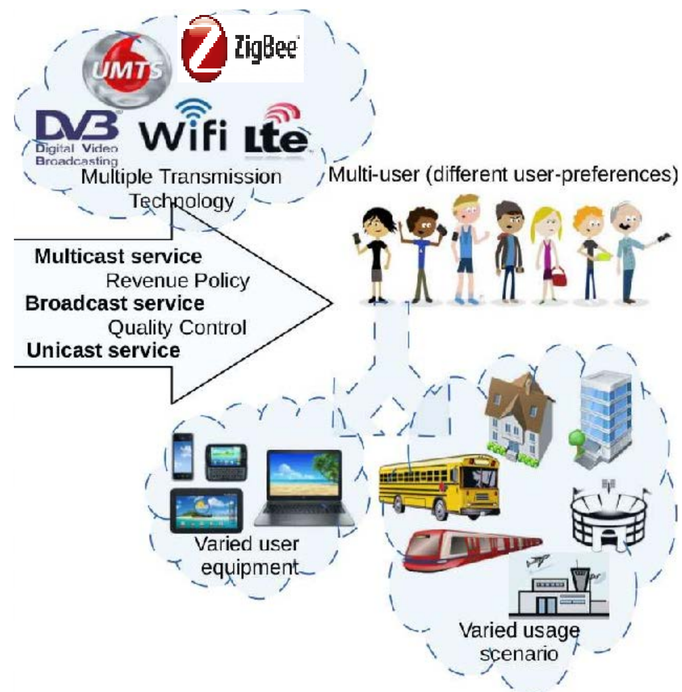
Effects

- Difficult/impossible interactions between platforms
- Lack of global resource directory & discovery
- Heterogeneous data semantics
- Difficult to distinguish infrastructure from service provider
- Traditional interaction models only

Issues related to data casting in 5G



- the user/device will increasingly act as a *prosumer*



proliferation of unicast, broadcast and multicast traffic flows originating from heterogeneous access segments (fed into the network by highly mobile devices)

Key players requirements

In environments characterized by highly dynamic & distributed communities

What **users** want is:

(i) generating **content for groups of devices** and delivering it in a highly flexible manner;

(ii) receiving only desired **traffic from reliable devices**, to face the risks of circulation of fake and harmful contents.

What **network operators** want is:

(i) Keep the network **load under control** to guarantee committed performance to users

(ii) Easily **handle traffic congestion** issues

Are current network primitives ready?

- Multiple unicast links are not an option (too many devices in 5G-IoT)
- Current multicast and broadcast network primitives are likely inadequate:
    - Multicast: underutilized
    - Broadcast: a "nightmare" for network operators due to associated risks of network overload
    - Geocast: too restrictive

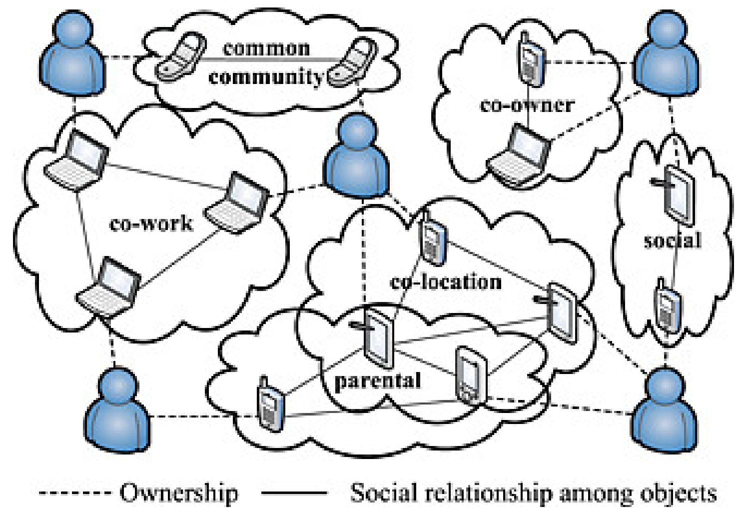
As a consequence...

- Design a new network primitive for group communications to:
    - manage plenty of H2H, H2M, and M2M data exchanges
    - support group communications in a flexible, reliable, and quickly (re)configurable way

Enabling paradigms

Let's start from two pillars of future 5G-IoT networks!

- the paradigm of "social networks of devices"
  - social ties create a social network of devices inherited from their owners
  - communication end-points identified in terms of social distance
  - device trustworthiness level computed by exploiting the view of the social network.



+

- the virtualization of both network resources (Software-defined Networking, SDN) and physical devices (object virtualization techniques).

First result: global system interoperability

Breaking down inter-system walls

- Global interoperability among heterogeneous IoT platforms achieved through end-device digital counterparts connected via social ties.

Second result: a new network primitive

Sociocast

=

- A social-driven networking primitive implemented by leveraging softwarization technologies and supporting group communications that span several heterogeneous systems.

❑ Enabling technologies

The IoT vision can be fully achieved only if objects are able to cooperate in an open way.

- Current implementations enable the cooperation among objects only if belonging to the same closed group.
- Sort of gateways are needed to allow inter-group communication and cooperation.
- The number of embedded computing and communication devices surrounding each of us will soon become too large:
  - Scalability problems will emerge
  - Efficient cooperation between smart objects creating trusted, dynamic social-like communities might contribute to solve the issue.

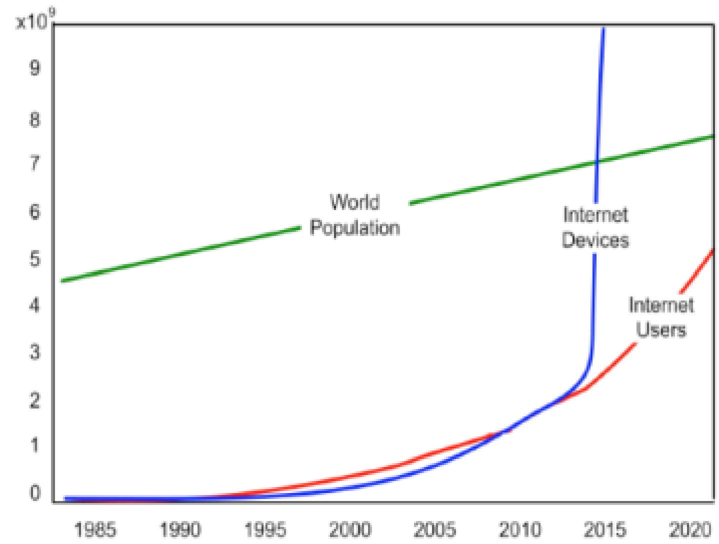


Figure: Number of people, Internet users, Internet devices: forecast.

…a matter of mental models

- Mental models are internal images or representations of something which people use all the time to make sense.
- People in general have little clue about how networks actually work, but most of us try to guess anyway, consciously or not.
- If a technology is not completely clear we make a guess on how it works by using a (usually simplified) mental model.
- As an example, technologies such as Wi-Fi, 3G or Bluetooth are simply called «wireless technologies» by using the concept of wire to give an idea on it working behavior

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this concept of mental model is taken from: A Social Web of Things by Joakim Forno, available at *http://www.ericsson.com/uxblog/2012/04/a-social-web-of-things/*

…a matter of mental models

source: www.computerlandbg.it

- A study conducted at the Ericsson User Experience Lab shows that the mental model associated to a network is something like "very many point-to-point connections"

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this concept of mental model is taken from: A Social Web of Things by Joakim Forno, available at http://www.ericsson.com/uxblog/2012/04/a-social-web-of-things/

…a matter of mental models

- The main issue with the Internet of Things will thus not be to understand what is IoT from the technological point of view but how it works (complex dynamics to exchange data , interact with the services offered by objects hidden everywhere, control of our private sphere, etc..)

- The old mental model related to cables is only sufficient to understand the technological side of the Internet of Things.

- But, to avoid confusions (and refusal) and to make interacting users feel comfortable with the novel IoT paradigm it is interesting to resort to a mental model that man has developed for thousands of years: social behavior and social relations that are the basis of other ecosystems, and other types of networks (not technological but human … for example)

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this concept of mental model is taken from: A Social Web of Things by Joakim Forno, available at *http://www.ericsson.com/uxblog/2012/04/a-social-web-of-things/*

…a matter of mental models

- Concepts of "friendship" and "social relationship" are very intuitive!
- Ericsson researchers think that a solution to both the practical scalability issues and the mental model/pedagogical issue could be to simply "dress" a network of things as if it was a social network!
- It is enough to envisage a social networks of objects with relevant services that allows them to interact, express in a natural way which data they need, which service they offer to users, collaborate with each other to create collective services to offer to the user.
- Deriving concepts are «Social Web of Objects» * and «Social Internet of Things » * *

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the concept of mental model is taken from: A Social Web of Things by Joakim Forno, available at http://www.ericsson.com/uxblog/2012/04/a-social-web-of-things/

** Andreas Fasbender, Joakim Formo, Marcus Gårdman, Takeshi Matsumura, U.S. patent, US20110161478 A1*

** * SIoT: Giving a Social Structure to the Internet of Things, L. Atzori, A. Iera, G. Morabito, IEEE Communications Letters, vol. 15, November 2011, p. 1193 -1195*

The need for social objects: an evolutionary approach

- Modern technologies have made "smart objects" available.
- We are now witnessing to a generational leap from objects with "*smartness*" to objects with "*social consciousness*".
- The evolutionary path towards the notion of objects that manifest a social behavior began years ago (around 2000).

"*res sapiens*"
(smart object)

"*res agens*"
(acting object)

"*res socialis*"
(social object)

L. Atzori, A. Iera, G Morabito, "From 'Smart Objects' to 'Social Objects': The Next Evolutionary Step of the Internet of Things" IEEE Communication Magazine, Networks, vol. 52, no. 1, 2014, pp. 97–105

What a "smart object" is?

Definitions

"an everyday artifact augmented with computing and communication, enabling it to establish and exchange information about itself with other artifacts and/or computer applications." *

"Smart objects might be able to not only to communicate with people and other smart objects, but also to discover where they are, which other objects are in the vicinity, and what has happened to them in the past." **

… evolution

"*spime*" (neologism for a currently theoretical object introduced by Sterling), which are *space-time* objects that are aware of their surroundings and can memorize real-world events ***

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* M. Beigl, H.-W. Gellersen, and A. Schmidt, "MediaCups: Experience with Design and Use of Computer-Augmented Everyday Objects," *Computer Networks*, vol. 35, no. 4, 2001, pp. 401–409

** F. Mattern, "From Smart Devices to Smart Everyday Objects," *Proc. Smart Objects Conf.* (SOC 03), Springer, 2003, pp. 15–16.

*** B. Sterling, *Shaping Things*, MIT Press, 2005.

What an “acting object” is?

- Recent researches addressed the issue of “smart” objects that exhibit pseudo-social behavior.
- An intense experimental activity involved everyday-life objects augmented in their capabilities to interact in modes which were inconceivable in the past
- The leap forward: distinction between a ‘thing’ that is simply connected to the Internet and a ‘thing’ with an active role in the network

… as a result:

- An “acting object” is an object that is able to translate the *awareness of causal relationships* - which are the basis of knowledge of change and evolution of its environment - *into actions*.
- a significant evolution in the concept of “spime” :
    - **the ability to *foment action and participate;***
    - **having an *assertive voice within the social web*.**

Examples of "acting object"

- The Smart-Its Friends procedure allows users to set temporary relationships of friendship on **Smart-Its**[*] (smart wireless devices, with sensing, processing, and communication functions) based on the devices' context.
- The so-called **Blog-jects**, a synonym for "objects that blog" [**] , are examples of this new attitude to a "*tight interaction with the world*".
- The theoretical concept of **Embodied Microblogging** (EM) [***] , proposes augmented everyday objects to : (i) mediate human-to-human communication and (ii) support additional ways for making noticeable and noticing activities in everyday life.
- Objects become able to develop a **spontaneous** networking infrastructure based on the information to be disseminated [****].

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[*] L. E. Holmquist, et al., "Smart-its friends: A technique for users to easily establish connections between smart artefacts," Proc. of ACM UbiComp'01.September/October 2001.

[**] J. Bleecker, "A Manifesto for Networked Objects " Proc. of the 13th MobileHCI, September 2006.

[***] E. Nazz and T. Sokoler, "Walky for Embodied Microblogging:sharing mundane activities through augmented everyday objects," Proc. of MobileHCI, September 2011.

[****] P. Mendes, "Social-driven Internet of Connected Objects," Proc. of the Interconnecting Smart Objects with the Internet Workshop, March 2011.

What a "social object" will be?

What we mean is an object that is part of and acts in a *social community of objects and devices* (which, in our case, is a Social Internet of Things).

Current open questions in the IoT arena:

- what really an object has to say to another object for which you really need an Internet of Things
- how these "conversations" between objects may promote the development of the human society

A social object for IoT adds further questions:

•*why objects should have their own social network, separated from that of humans, if they are not supposed to call each other to agree to go clubbing by themselves (at least for the next years)?*

A director of science fiction movies has thousands of answers!

....but as pragmatic computer scientists and engineers we must focus on interesting **use cases** to implement!

Networks of social IoT objects

Two different approaches towards a network of Social IoT objects:

Social Web of Things (Social-WoT)

According to this vision there is an ecosystem that allows people and smart devices to interact within a social framework (Crespi) Web technologies are used in such systems to provide services *.

Social Internet of Things (S-IoT)

According to this vision Objects can also autonomously establish social relationships with each other and create social communities *separated* from those of human beings but *subservient* to their needs **.

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* A. M. Ortiz et al., "The cluster between internet of things and social networks: Review and research challenges“, *Internet of Things Journal, IEEE,* 1.3 (2014): 206-215 .

** *L. Atzori, A. Iera, G. Morabito, "SIoT: Giving a Social Structure to the Internet of Things", IEEE COMMUNICATIONS LETTERS, Vol. 15, No. 11, pp.: 1193-1195. Nov. 2011.*

** *L. Atzori, A. Iera, G. Morabito, M. Nitti, " The Social Internet of Things (SIoT) – When social networks meet the Internet of Things: Concept, architecture and network characterization ", Computer Networks, Volume 56, Issue 16, 14 Nov. 2012, Elsevier.*

Main peculiarities

- online social networks and their APIs used to allow smart objects to communicate with users by relying on Web protocols [a].
- users' social network accounts supports service operations for IoT, such as using location data or publishing device status [b].
- social networks used as an interface to control smart objects [c].
- collaboration between social networks and smart objects, to enable smart devices to "talk" with other objects, to share experience about certain situations and to seek help [d].
- people share services offered by smart objects with friends/objects [e].

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[a] D. Guinard, "A web of things application architecture: integrating the real-world into the web", Ph.D. dissertation, 2011.

[b] A. Pintus et al., "Paraimpu: a platform for a social web of things", ACM World Wide Web Conf. 2012.

[c] C. Zhang, et al., "Architecture design for social web of things", ACM Workshop on Context Discovery and Data Mining 2012

[d] J. I. Vazquez and D. Lopez-De-Ipina, "Social devices: autonomous artifacts that communicate on the internet," in The Internet of Things, Springer, 2008, pp. 308–324.

[e] D. Guinard, et al., "Sharing using social networks in a composable web of things", IEEE PERCOM, 2010.

SIoT (Social Internet of Things)

a novel paradigm of "social network of intelligent objects", based on the notion of social relationships among objects[a,b] .

[a] *L. Atzori, A. Iera, G. Morabito, "SIoT: Giving a Social Structure to the Internet of Things", IEEE COMMUNICATIONS LETTERS, Vol. 15, No. 11, pp.: 1193-1195. Nov. 2011.*

[b] *L. Atzori, A. Iera, G. Morabito, M. Nitti, "The Social Internet of Things (SIoT) – When social networks meet the Internet of Things: Concept, architecture and network characterization", Computer Networks, Volume 56, Issue 16, 14 Nov. 2012, Elsevier.*

Objectives of the social relationships established **between social objects** are twofold:

- Give the IoT a **structure that can be shaped** as required **to guarantee network navigability**[c] so as that service discovery can be performed effectively while guaranteeing scalability.
- Create **a level of trustworthiness** which could be used to leverage the level of interaction between things that are "friends".

[c] *J. Kleinberg, "The small-world phenomenon: an algorithmic perspective" in Proc. of ACM Symposium on Theory and Computing, 2000.*

Why things should socialize?

What a social network allows to do, and why it matters to people and things?

Reason	Humans	Things
Become visible	Increase popularity	Publish information/services
Find resources	Find old friends	Find information/services
Obtain context information	Get filtered information	Get environment characteristics
Discover new resources	Find new friends	Find new services/updated information

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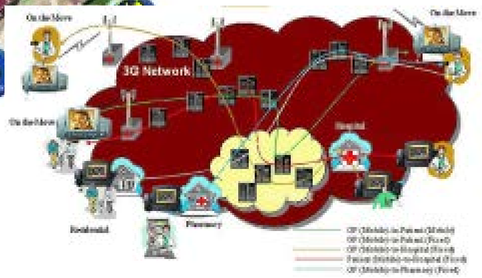
Defining a kind of social behavior among objects.

Which social relationships things can be engaged in?

Parental object relationship: defined among similar objects, built in the same period by the same manufacturer.



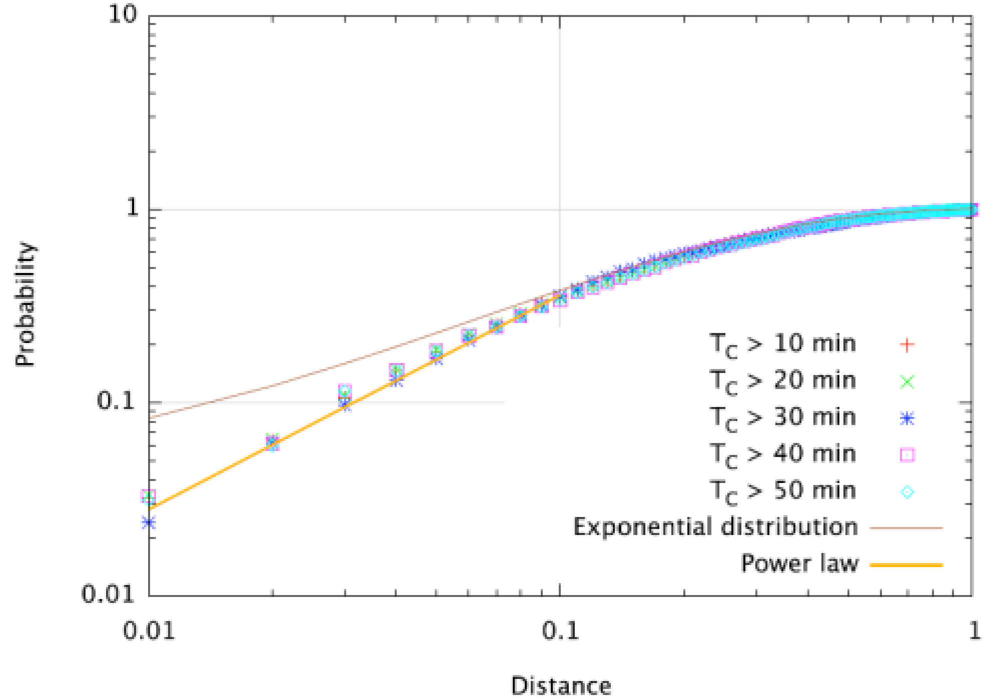
Co-location object relationship and **co-work object relationship**: determined whenever objects (e.g., sensors, actuators, RFID Tags, etc.) constantly reside in the same place (home/industrial automation services) or periodically cooperate to provide a common IoT application (emergency response, telemedicine, etc).

Social object relationship: established when objects come into contact, sporadically or continuously, for reasons purely related to relations among their owners

Ownership object relationship: defined for objects owned by the same user (mobile phones, game consoles, etc.).

- Characteristics of the SIoT
  - Small diameter
  - Navigable
  - Locality (in several senses: geographic, interactions)

Social Object Relationships (SOR)



L. Atzori, A. Iera, G. Morabito, SIoT: giving a social structure to the Internet of Things. *IEEE Communication Letters*. 2011.
L. Atzori, A. Iera, G. Morabito, M. Nitti, The social internet of things (siot)–when social networks meet the internet of things: Concept, architecture and network characterization. *Computer Networks.* 2012.

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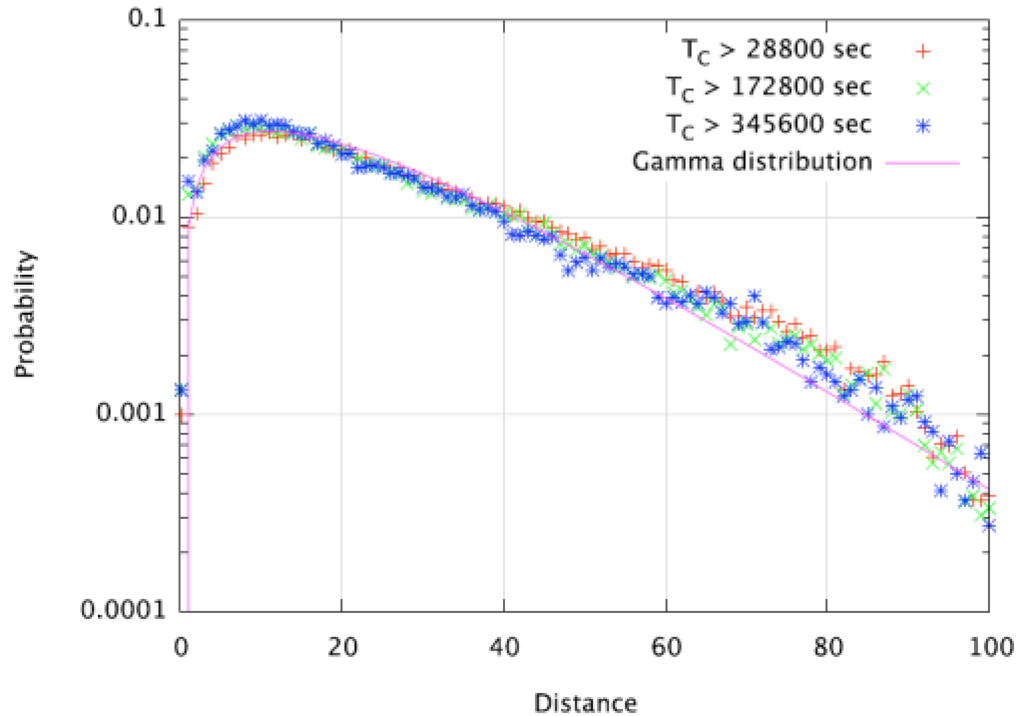
Co-work Object Relationships (SOR)



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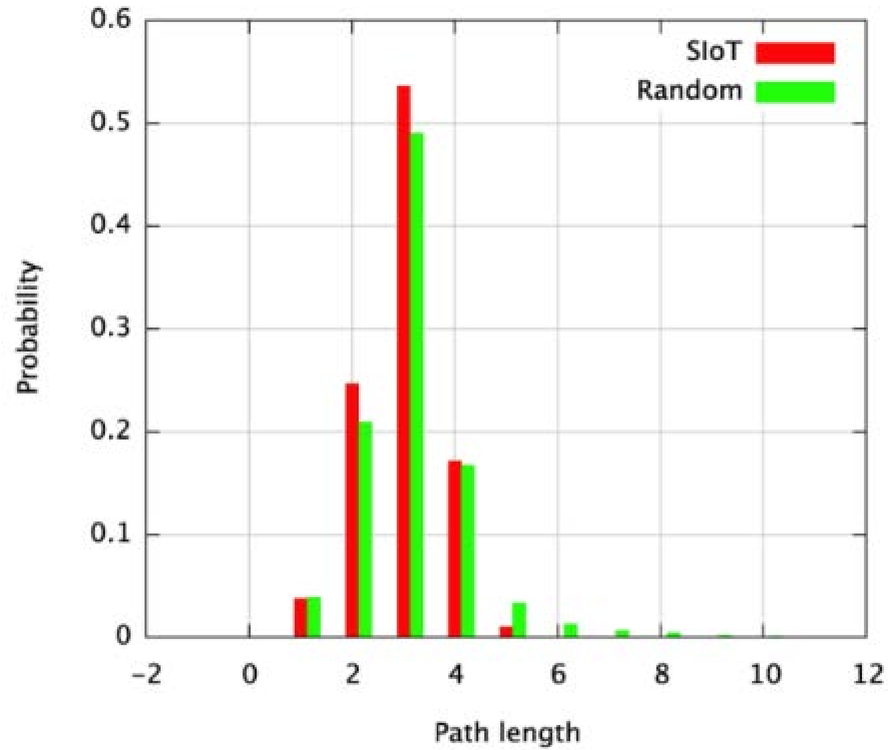
Distribution of the distance between pair of nodes



L. Atzori, A. Iera, G. Morabito, SIoT: giving a social structure to the Internet of Things. *IEEE Communication Letters*. 2011.
L. Atzori, A. Iera, G. Morabito, M. Nitti, The social internet of things (siot)–when social networks meet the internet of things: Concept, architecture and network characterization. *Computer Networks.* 2012.

- **Goal:** Evaluate trustworthiness of nodes in a distributed manner considering the existence of malicious nodes

- The trustworthiness value that node *i* assigns to node *j* is the result of
  - Direct experience of the behavior of *j* observed by *i*
  - Reputation of node *j* (in the view of nodes that are friends of *i*)
  - Historical data and current observations

M. Nitti, R. Girau, and L. Atzori, "Tustworthiness Management in the Social Internet of Things", IEEE Trans. On Knowledge and Data Engineering, 2014.

I.R. Chen, F. Bao, and J. Guo. "Trust-based Service Management for Social Internet of Things Systems", IEEE Trans. on Dependable and Secure Computing, 2015

2011-2018: 7 years in SIoT

Academic

- Focusing on specific issues and refinements
  - Security/trustworthiness support
  - Policies to build relationships
  - Implementations
- Speeches/tutorials/lessons
- Research projects
- Trying to maximize impact
  - Citations
  - Building a community

Industrial

- Consulting for vertical markets
  - Logistics
  - Manufacturing
  - Smart cities
  - eHealth

2. Cloud-computing

...a matter of virtualization

Integrating the **Internet of Things** with **Cloud Computing** clearly emerges as the frontier of research and development activities on this new paradigm...

Source: jp.imgtec.com/flowcloud/

Cloud-computing-centric architectures

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

M. Peter, G. Timothy, "The NIST Definition of Cloud Computing, Recommendations of the National Institute of Standards and Technology", National Institute of Standards and Technology (NIST), Special Publication 800-145, Washington, 2011

Service models@NIST

- ✓Infrastructure as a Service (IaaS): the client is offered storage, processing and network resources on which to run applications and operating systems
- ✓Platform as a Service (PaaS): the client is offered an application development and hosting environment on a cloud infrastructure
- ✓Software as a Service (SaaS): the client is offered the possibility of using provider applications made available via the web on a cloud infrastructure

M. Peter, G. Timothy, "The NIST Definition of Cloud Computing, Recommendations of the National Institute of Standards and Technology", National Institute of Standards and Technology (NIST), Special Publication 800-145, Washington, 2011

Service models@NIST

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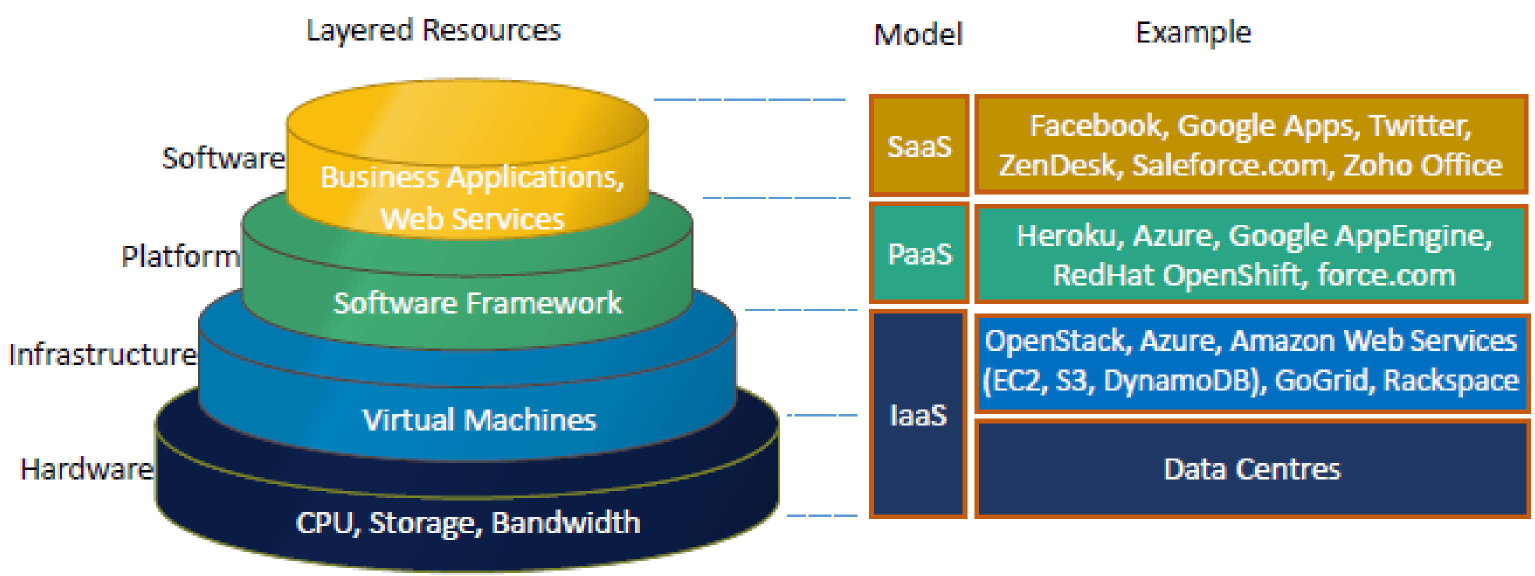


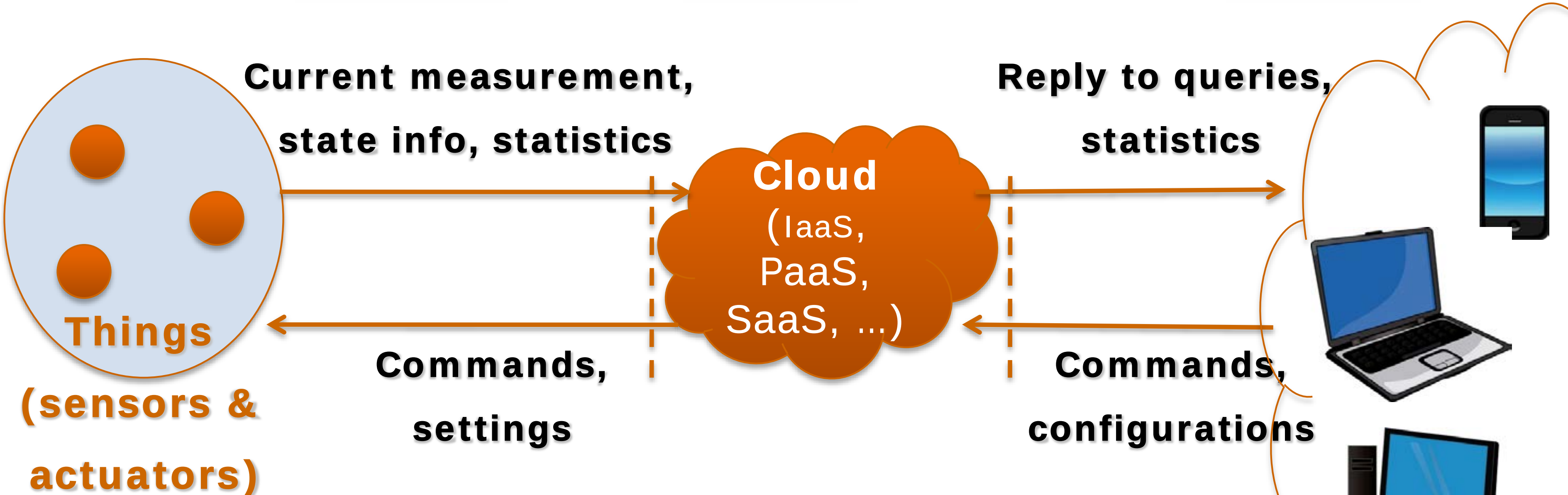
M. Peter, G. Timothy, “The NIST Definition of Cloud Computing, Recommendations of the National Institute of Standards and Technology”, National Institute of Standards and Technology (NIST), Special Publication 800-145, Washington, 2011

Handling constraints

- **Requirement:** services and applications want to access objects anywhere and anytime; furthermore they might need historical data
- **Constraints:**
  - In certain application scenarios objects have intermittent connectivity (e.g., RFID tag) → They are not reachable *anywhere*
  - In most application scenarios objects spend a large portion of time in “idle” state to save energy → They are not reachable *anytime*
  - Most objects have limited storage capabilities → They do not store *historical data*

Step 1: The Things in the Cloud

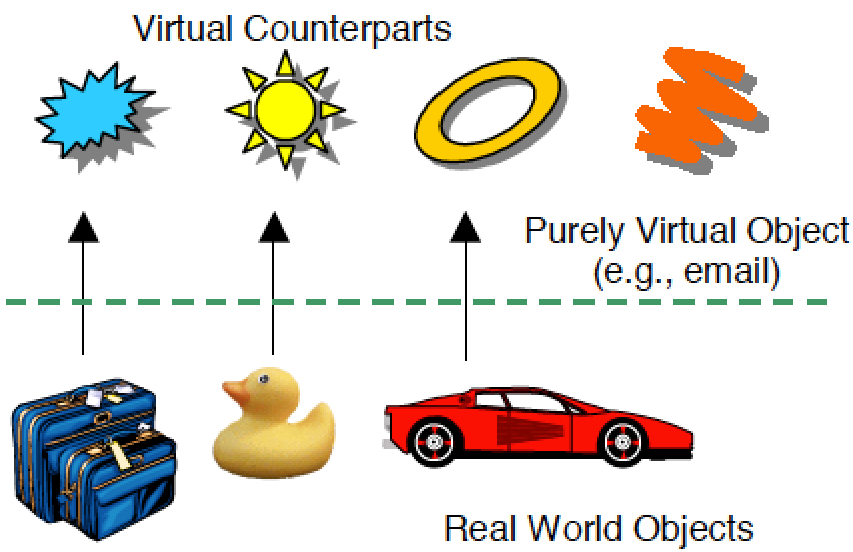
General approach



- Value proposition:
  - Objects owners: maximum exposure of data
  - Application developers: huge number of sensors available
- Separate applications from objects → The same objects can be used by several applications → **Multitenancy**!
- Open API for third party developers

The Virtual Object (VO)

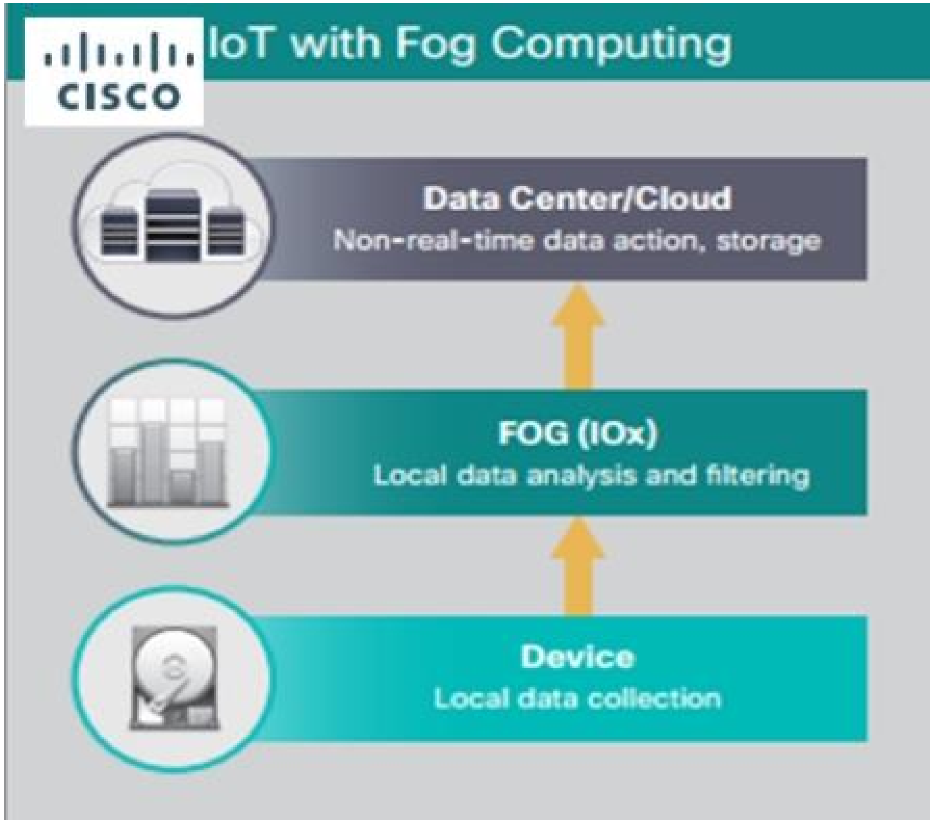
- It is a *digital representation or virtual counterpart of a real world object*
  - It can run everywhere, even distributed in different locations
    - ✓ However, it prefers the cloud for its elastic resource provisioning
  - It is the spokesperson for the physical entity
  - It fosters reusability, robustness, intelligence, context-awarness
- First appearance in 2000
  - It represents the access points of the real-world objects to the infrastructure to interact with the virtual world*



*M. Langheinrich *et al*, “First steps towards an event-based infrastructure for smart things,”, in Ubiquitous Computing Workshop, 2000.

Step 2: The Things in the Edge Cloud

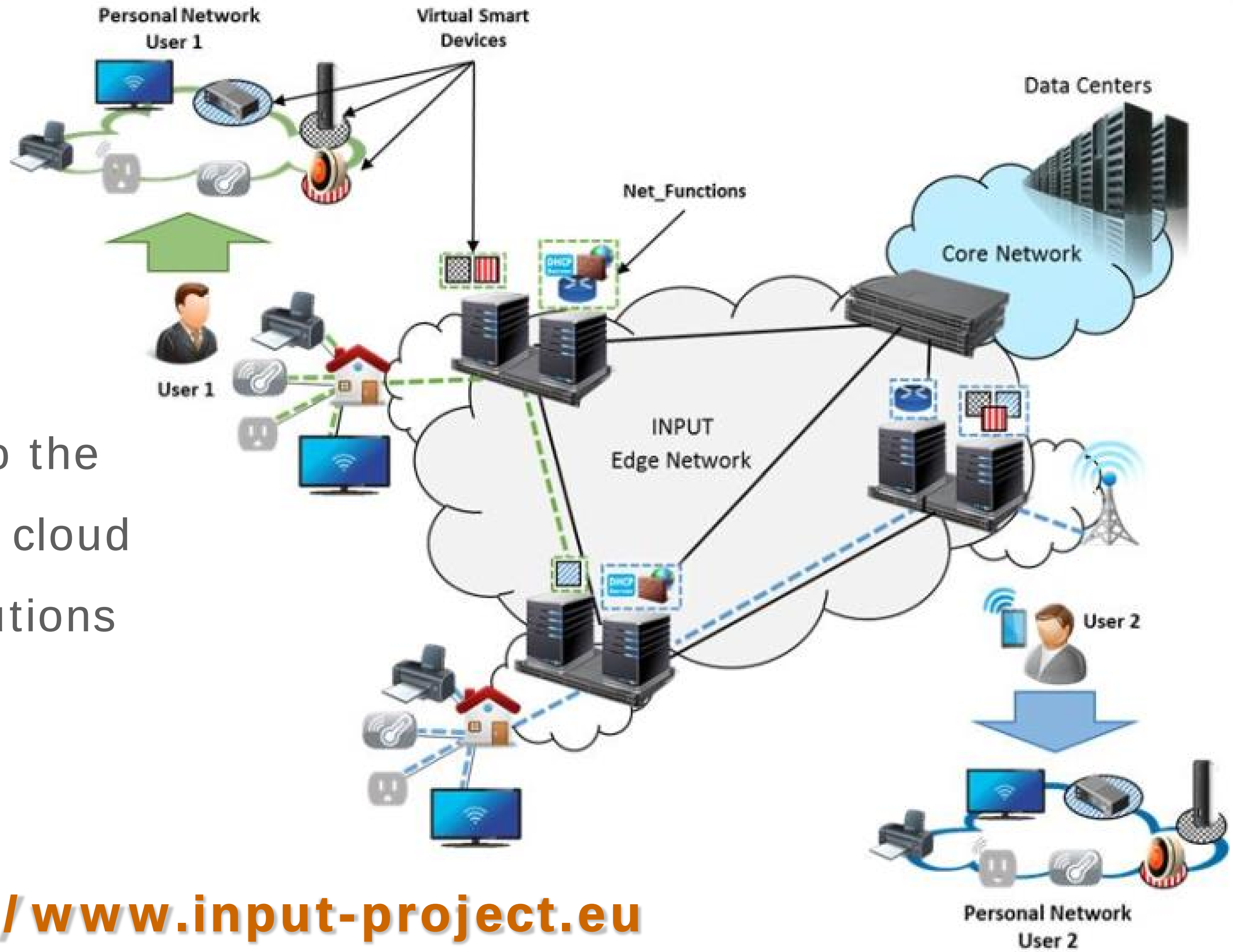
Fog computing: The fog extends the cloud to be closer to the things that produce and act on IoT data (@Cisco-2012)



- Fog nodes, **can be deployed anywhere** with a network connection: on a factory floor, alongside a railway track, in a vehicle.
- Any device with **computing, storage, and network connectivity can be a fog node**, e.g., industrial controllers, switches, routers, embedded servers, and video surveillance cameras.

White Paper, "Fog Computing and the Internet of Things: Extend the Cloud to Where the Things Are", 2015, Cisco

The INPUT example



- A solution to the high latency of cloud computing solutions

http://www.input-project.eu

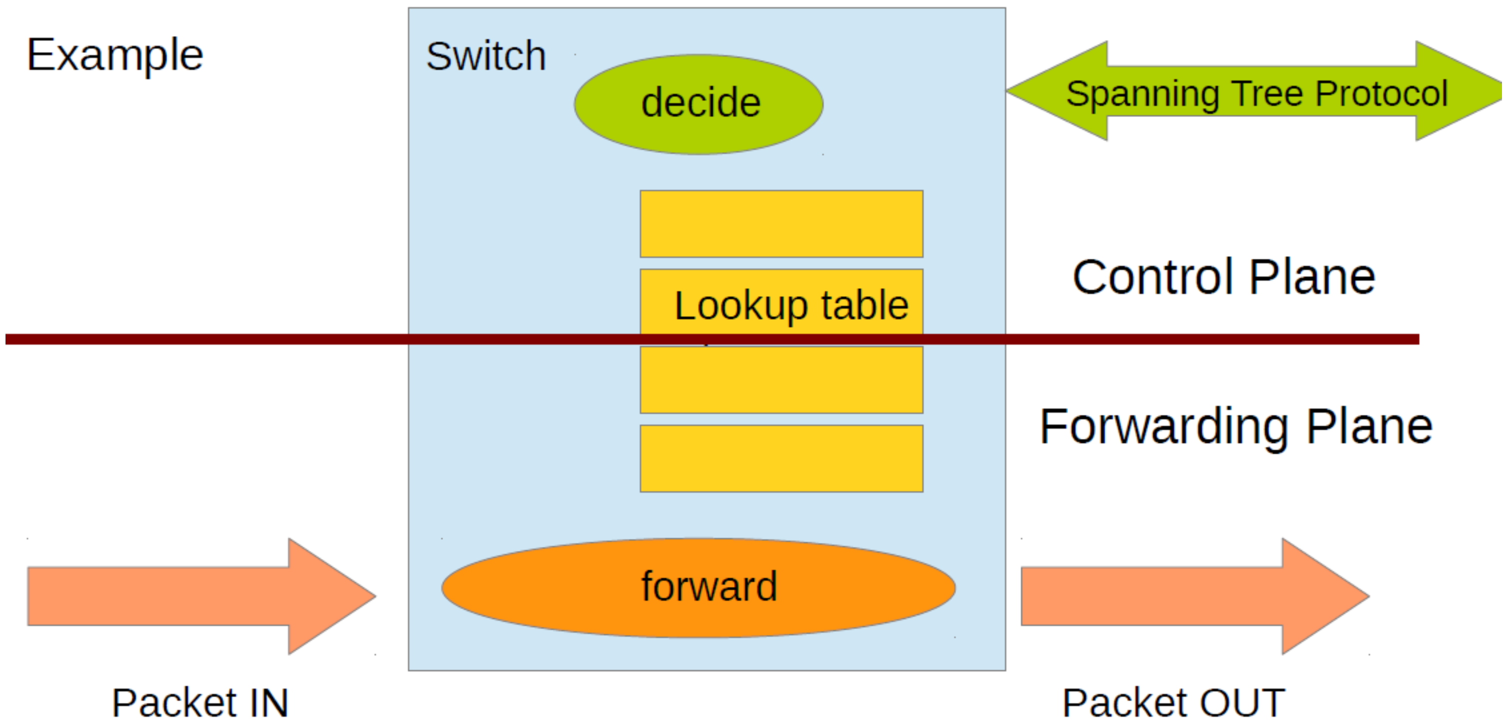
to deepen the knowledge…

I Farris, R Girau, L Militano, M Nitti, L Atzori, A Iera, G Morabito. “Social Virtual Objects in the Edge Cloud”. *IEEE Cloud Computing*.

Atzori L, Bellido J L, Bolla R, Genovese G, Iera A, Jara A, Lombardo C, Morabito G (2019). SDN&NFV contribution to IoT objects virtualization. *COMPUTER NETWORKS*, vol. 149, p. 200-212, ISSN: 1389-1286

Farris I., Orsino A., Militano L., Iera A., Araniti G. (2018). Federated IoT services leveraging 5G technologies at the edge, *Ad Hoc Networks*, 68, 58-69.

- **Status quo in Networking** : a data plane is responsible for forwarding user packets using information provided by the control plane (e.g. forwarding tables)



Status quo in Networking

- Control and Data planes are tightly coupled, **embedded in the same device** reducing flexibility and hindering evolution of the networking infrastructure

- Development and deployment of **new networking features imply** a modification of the control plane of all devices, **installation of new firmware/HW upgrades**

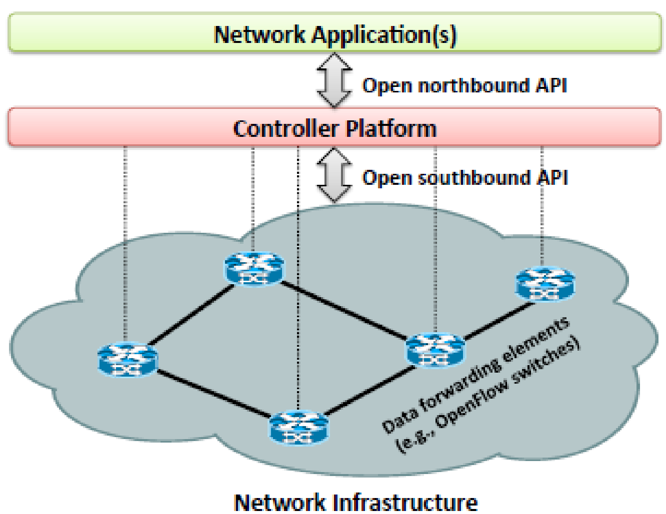
consequence

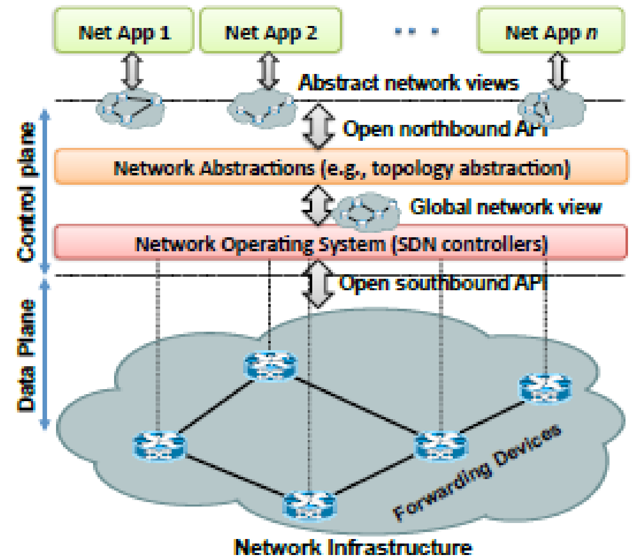
- Despite their widespread adoption, traditional **IP networks are complex and hard to manage**
- Network operators need to configure each individual device separately using low-level and often **vendor-specific commands**
- High capital and operational costs (CAPEX, OPEX)
- Myriad of **specialized components** and middleboxes (e.g., firewall, intrusion detection)

SDN pillars

SDN can be defined as a network architecture build upon 4 pillars:

- The control and data planes are **decoupled**.
- Forwarding decisions are **flow-based**, instead of destination-based.
- Control logic is moved to the SDN **controller** (NOS)
- The network is **programmable** through software applications





SDN pillars

- **The control and data planes are decoupled**. Control functionality is removed from network devices that become simple forwarding elements.

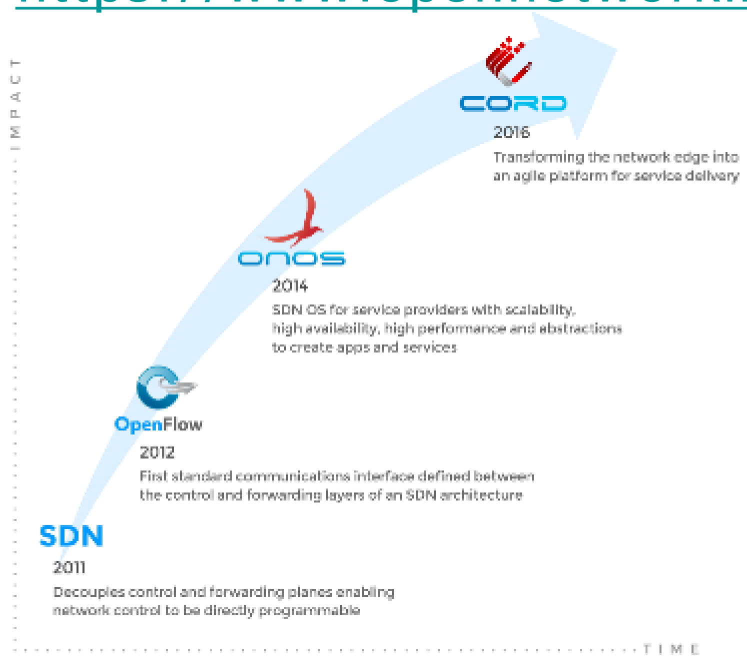
- **Forwarding decisions are flow-based**, instead of destination-based. A flow is broadly defined by a set of packet field values acting as a match (filter) criterion. It is a sequence of packets between a source and a destination.

- **Control logic is moved to an external entity**, the so-called SDN controller or Network Operating System (NOS), i.e. a software platform that runs on commodity servers and provides resources and abstractions to facilitate the programming of forwarding devices based on a logically centralized, abstract network view.

- **The network is programmable** through software applications running on top of the NOS that interacts with the underlying data plane devices.

SDN standardization

- SDOs (Standard Development Organizations)
  - IEEE, IETF, ETSI
- Industrial/Community consortia
  - ONF (Open Network Foundation) https://www.opennetworking.org/about/onf-overview

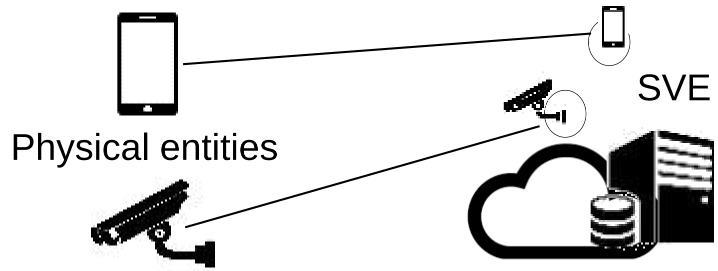


OPEN NETWORKING FOUNDATION

- **Global system interoperability**

Social Virtual Entities

- A SVE is a digital representation of a physical entity running in a server



- SVEs can create *autonomously* social-like relationships with each others, stored in a Friend Table

- Different types of relationships exist:
  - Co-location object relationships (CGLOR)
  - Co-working object relationships (CWOR)
  - Parental object relationships (POR)
  - Co-ownerships object relationships (OOR)

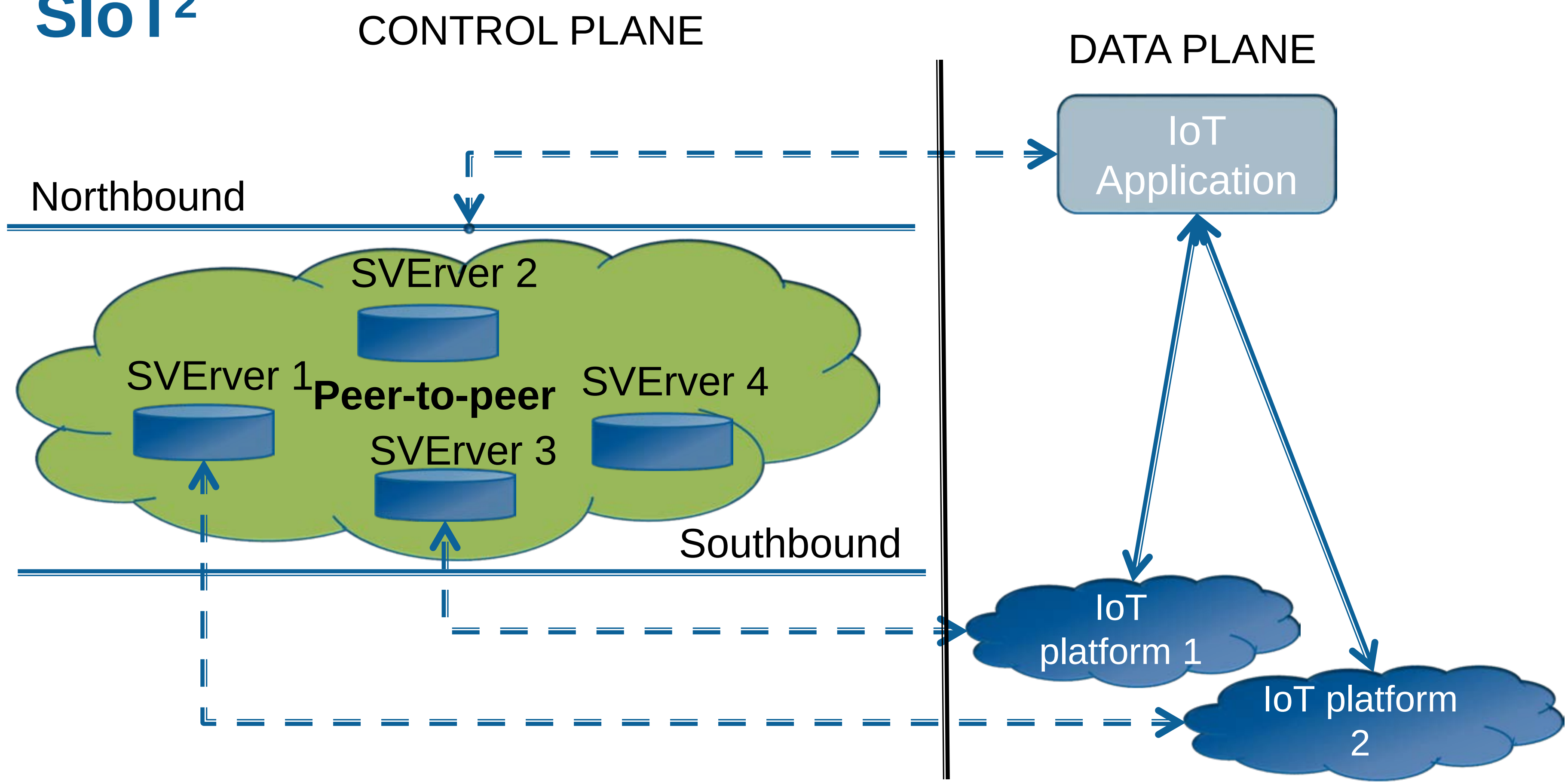
Friend table example

Entity ID	Metadata	Relationship type	SVE locator
ID_A	logistics	CWOR	151.70.25.10
ID_E	sport	CGLCOR	130.40.0.56
ID_D	infotainment	POR	130.40.0.56

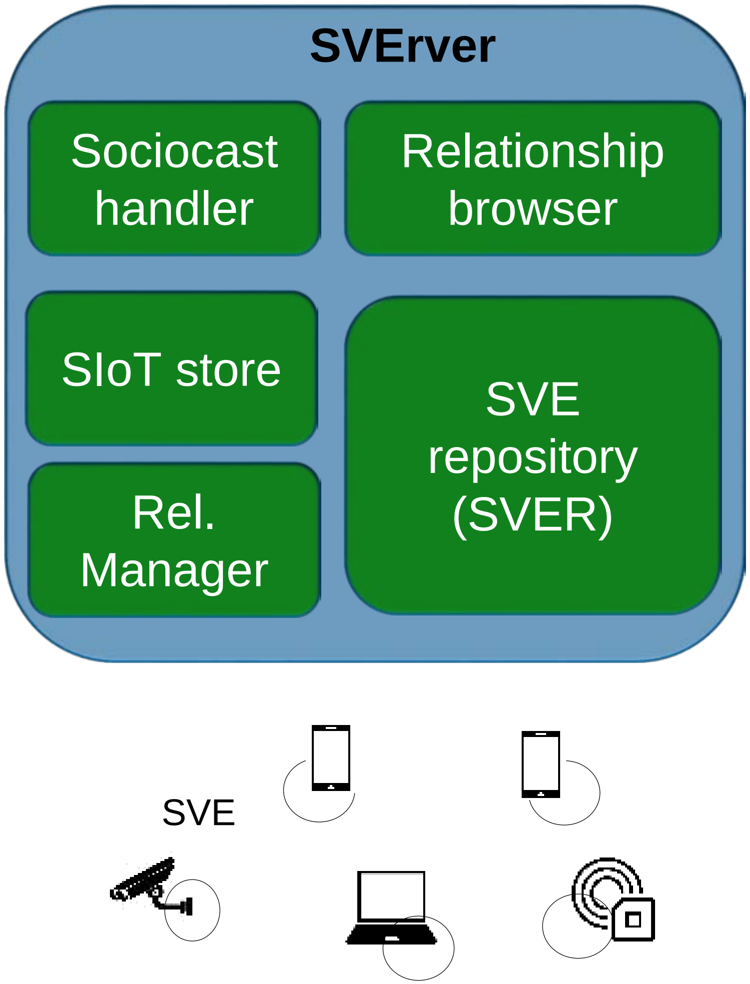
- Others can be defined and the logic is represented in the SVE itself

L. Atzori, C. Campolo, B. Da, A. Iera, G. Morabito, P. P. Esnault, S. Quattropani. Social-IoT Enabled Identifier/Locator Splitting: Concept, Architecture, and Performance Evaluation. IEEE ICC 2018.

SIoT²


CONTROL PLANE
DATA PLANE
IoT Application
Northbound
SVErver 2
SVErver 1
Peer-to-peer
SVErver 4
SVErver 3
Southbound
IoT platform 1
IoT platform 2

SVErver components



- The **SVER** is a database storing SVEs
- The **Relationships manager** is responsible of the lifecycle of social relationships established between SVEs
- The **Relationship browser** is used by applications (as well as the sociocast) to navigate the SIoT
- The **SIoT store** is a distributed market place for SIoT applications
- The **sociocast** component supports new communication configurations
  - Beyond unicast, broadcast, multicast, anycast, etc…

❑ Sociocast: a new network primitive

Previous approaches

Social ties among devices already used to improve traditional communications paradigms at a ~~middleware, application or cross- layer~~.

- forward data by limiting the number of relays until destination in multi-hop wireless (*opportunistic* and *delay-tolerant*) networks.
- identify the best data carriers through predictions based on social interactions (*SocialCast*, a routing framework for publish-subscribe).
- implement a *social anycast* communication service in DTN.
- implement video content sharing in Social-aware video multiCast (SoCast) systems to stimulate cooperation among mobile clients.

Idea: to leverage the "social network of devices" paradigm at the network layer

____
L. Atzori, A. Iera, G. Morabito (2019), "Sociocast: A New Network Primitive for IoT", IEEE Communications Magazine, June 2019, Vol. 57, n. 6, Digital Object Identifier: 10.1109/MCOM.2019.1800917

Why we need a "socio"-cast primitive?

The need for a tool to support traditional IP multicast.

- a primitive used by network operators to filter the set of nodes that can join a certain multicast group, based on their position in the social graph of devices.

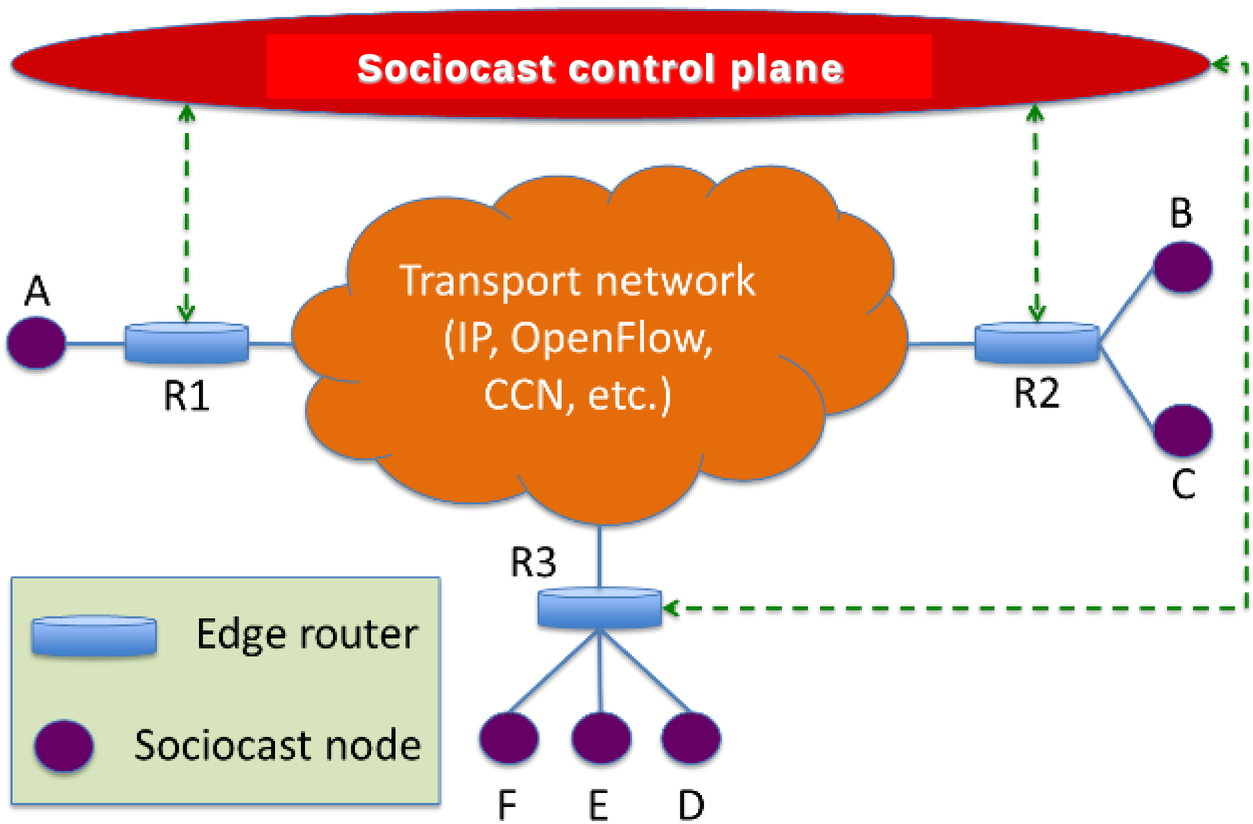
The need for a dynamic & selective firewall.

- The filtering of the entities that can send it data can leverage:
  - trustworthiness control policies offered by a social network of devices (like in human social networks)
  - the reciprocal position in the social network

The need for higher flexibility in data casting.

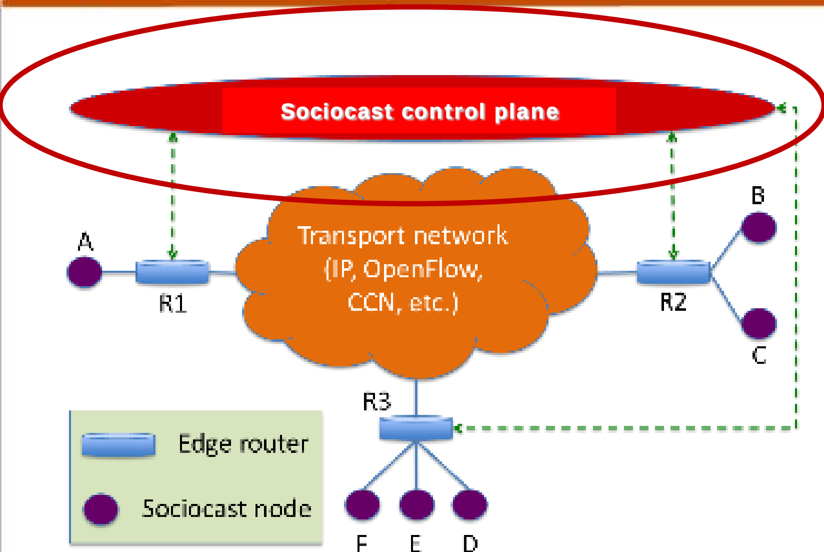
- Introduce a network primitive that can make use of data structures, defined in the control plane at the network layer, containing basic metadata for device description.

The framework supporting the Sociocast primitive



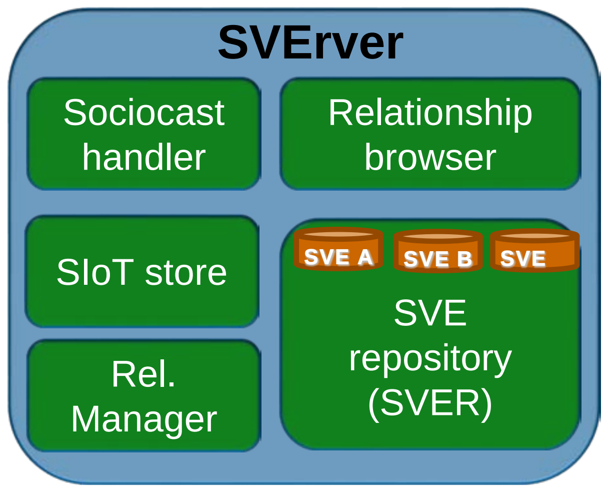
Early stage of introduction of Sociocast: a new network control plane functionality coupled with existing transport networks.

The Sociocast control plane

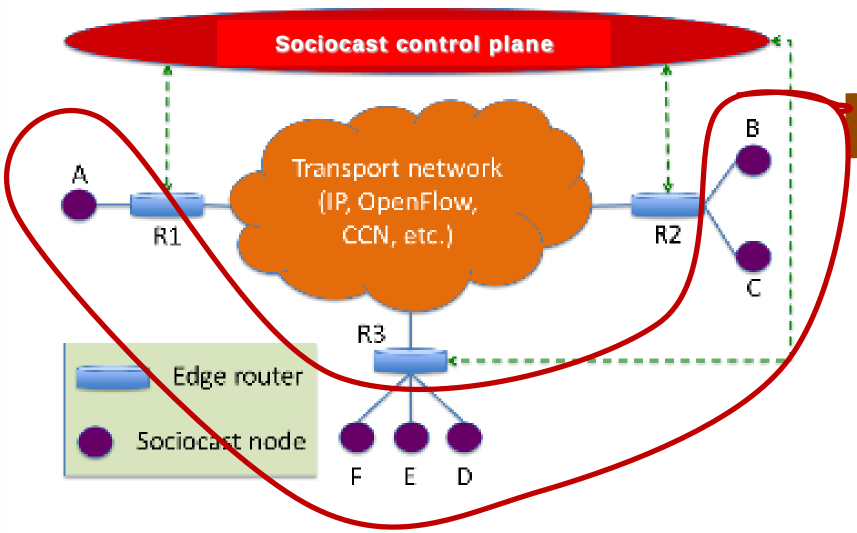


The Sociocast control plane must implement a set of control plane functionalities relying on a distributed hardware/software infrastructure.

Major components of the Sociocast control plane are the SVErvers



The Sociocast nodes



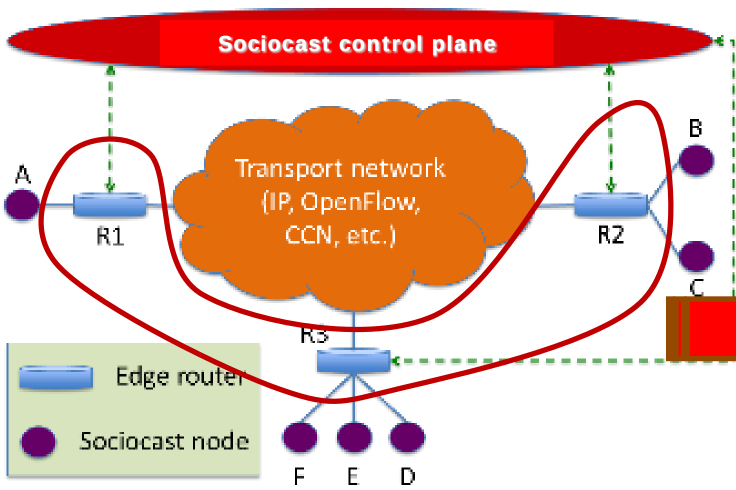
Sociocast nodes exploit the new network primitive to deliver packets to a set of destinations on the basis of their mutual position in the Sociocast social graph.

Friend table example

Entity ID	Metadata	Relationship type	SVE locator
ID_A	logistics	CWOR	151.70.25.10
ID_E	sport	CGLCOR	130.40.0.56
ID_D	infotainment	POR	130.40.0.56

The *Social Virtual Entity* (SVE) , with its "*Friends Table*", stored in the SVER is the digital counterpart of each IoT node

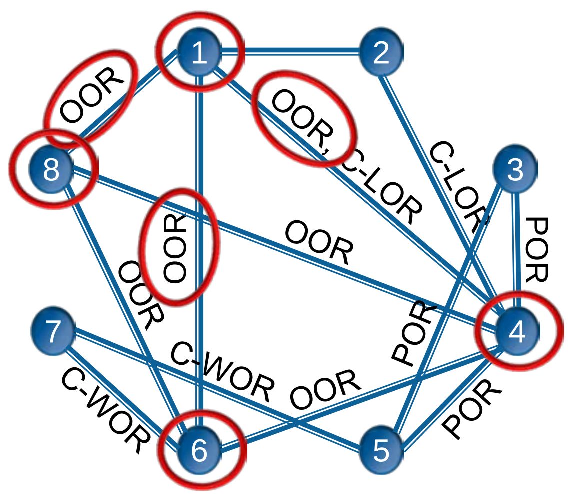
The Sociocast Edge routers



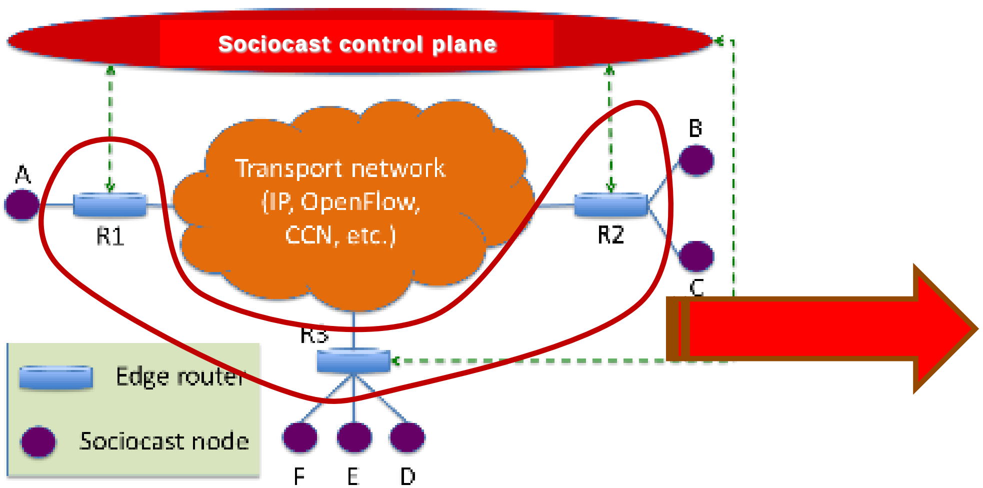
Edge routers are a key component that must intercept incoming packets with certain characteristics, interpret them, interact with the Sociocast control plane, and execute corresponding commands

- *Sociocast* allows to select:
  - The destinations of a packet based on the position of their SVEs in the social network

Sample case: eHealth monitoring systems



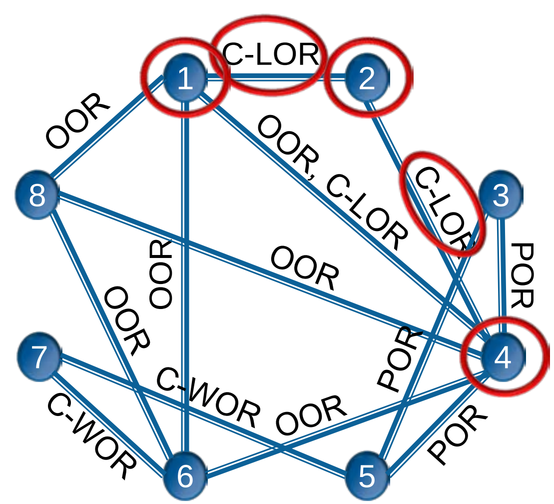
The Sociocast Edge routers



Edge routers are a key component that must intercept incoming packets with certain characteristics, interpret them, interact with the Sociocast control plane, and execute corresponding commands

- *Sociocast* allows to select:
  - The nodes allowed to transmit packets to a certain node based on the positions of their SVEs in the social network

Sample case: travel assistance in I.T.S.



❑ Implementation issues

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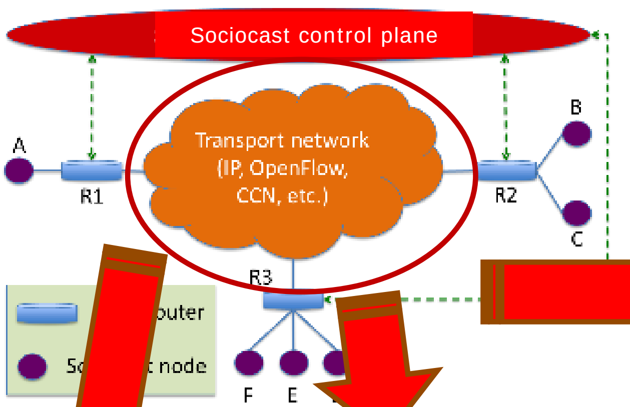
Sociocast support in current networks



IP Network

- Sociocast exploits IP multicast to increase network efficiency
  - assigns an IP multicast address to the communication & notifies it to R1, R2, R3.
  - The above edge *routers will join the multicast group* and the packet will be transported in the network along the multicast tree.

OpenFlow Network

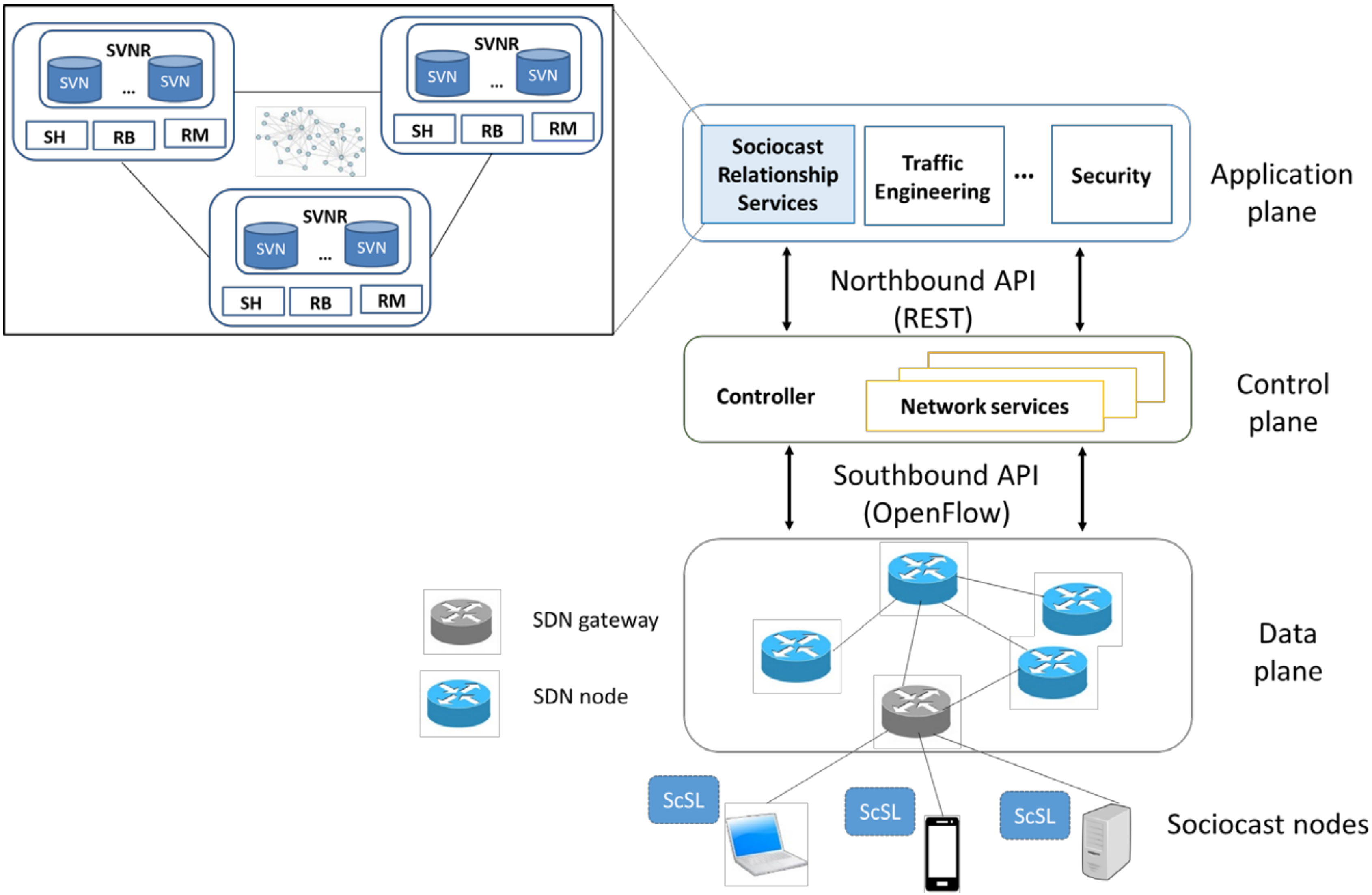
- Sociocast as a network application running on top of a Controller.
  - R1, R2, and R3 are OpenFlow switches able to distinguish incoming packets generated by the Sociocast primitive.
  - R1 sends packets to Controller, which forwards it to Control Plane
  - Control plane identifies destinations and provides the list to the Controller that instructs the Flow Tables of Core Network switches.

A testbed is under deployment

Publish-subscribe Network

- A major difference is that R2 and R3 are responsible to issue the subscription messages for the packets transmitted by node A with a certain label.

Sociocast support in SDN networks



Proof-of-concept initial tests

- reference scenario

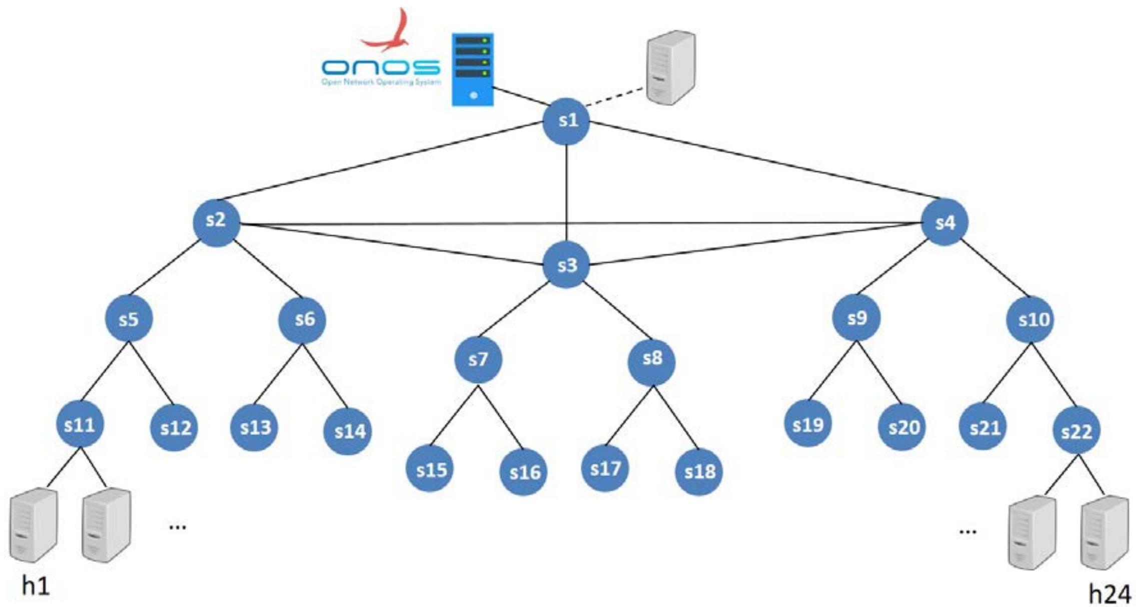
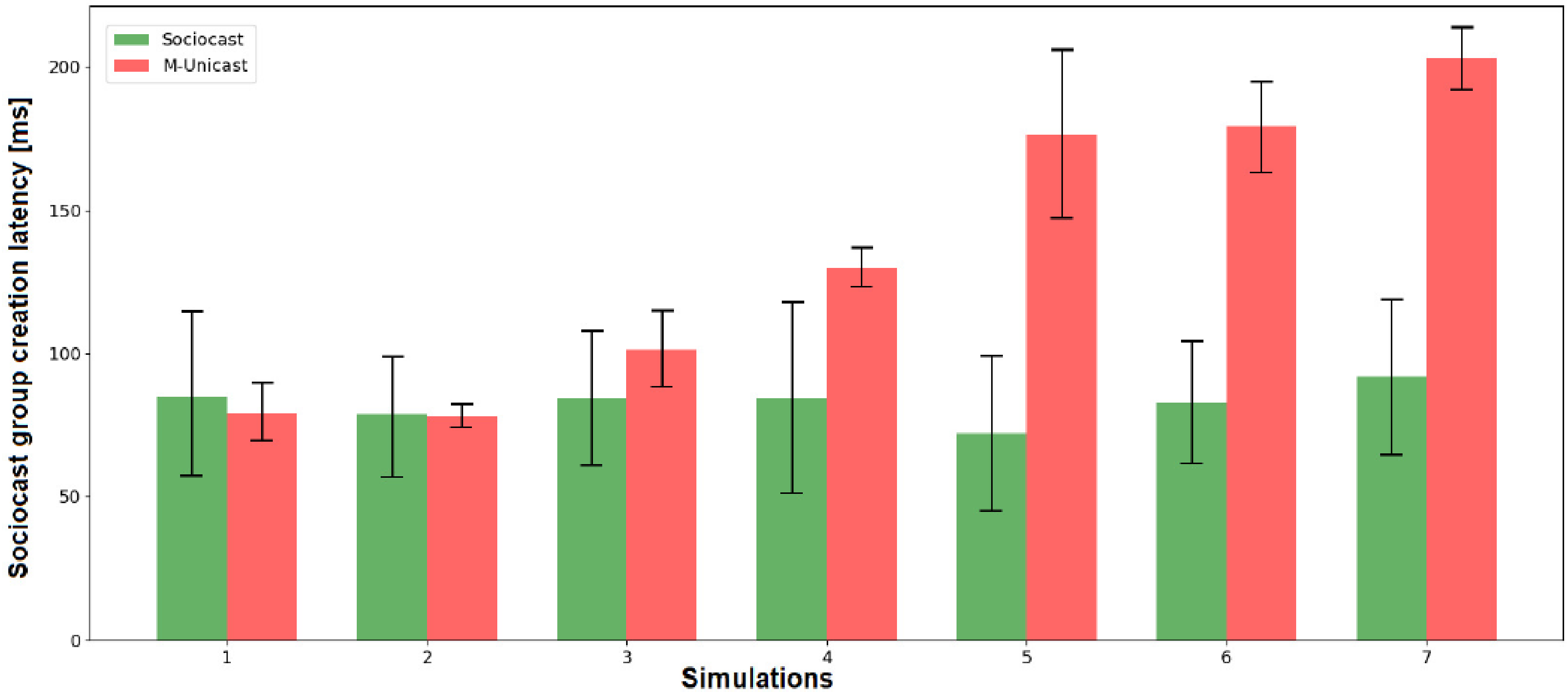


TABLE I
PROBABILITIES OF SOCIAL RELATIONSHIP ESTABLISHMENT.

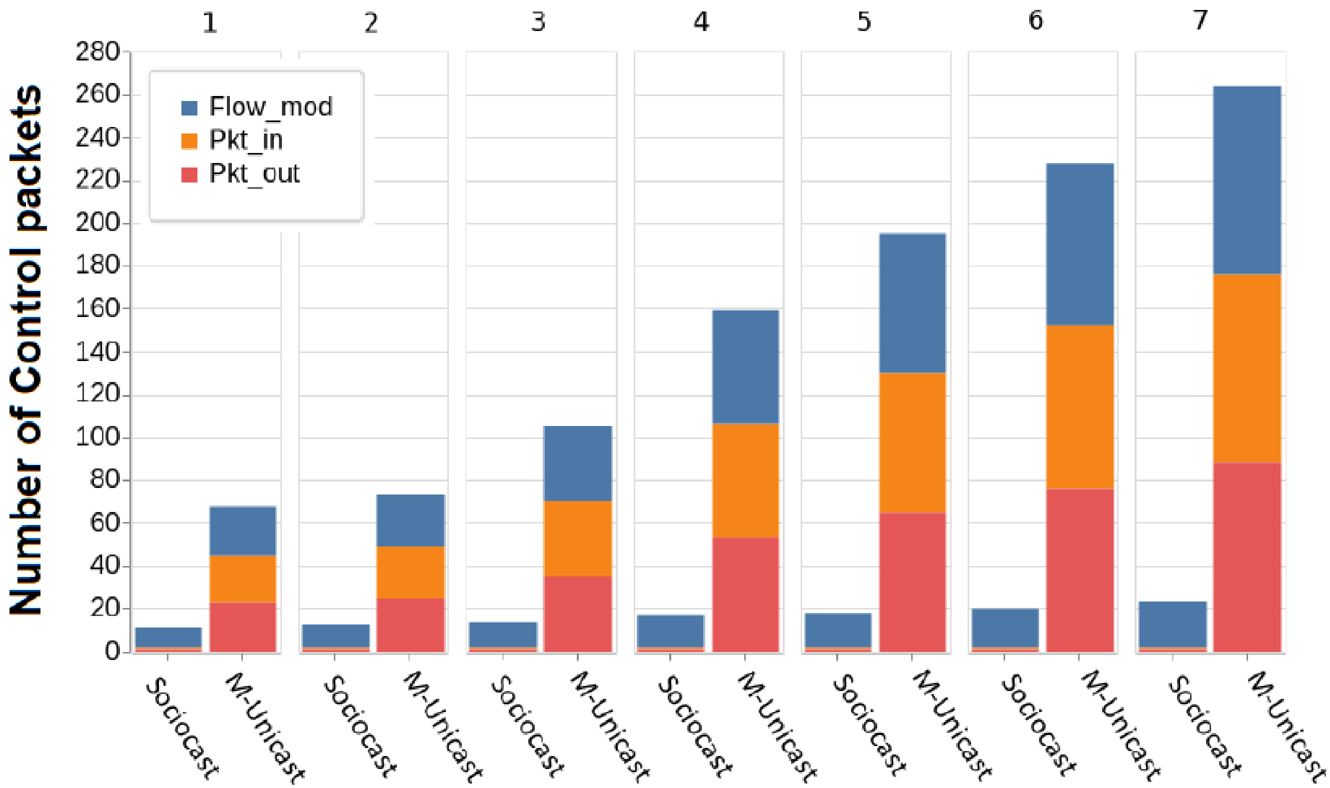
Sim. ID	Average Destinations	$p_{soc,1}$	$p_{soc,2}$	$p_{soc,3}$	$p_{soc,4}$
1	4.5	0.1	0.2	0.3	0.4
2	5.5	0.2	0.3	0.4	0.5
3	8.4	0.3	0.4	0.5	0.6
4	11.2	0.4	0.5	0.6	0.7
5	12.7	0.5	0.6	0.7	0.8
6	15.3	0.6	0.7	0.8	0.9
7	18.4	0.7	0.8	0.9	1

Proof-of-concept initial tests



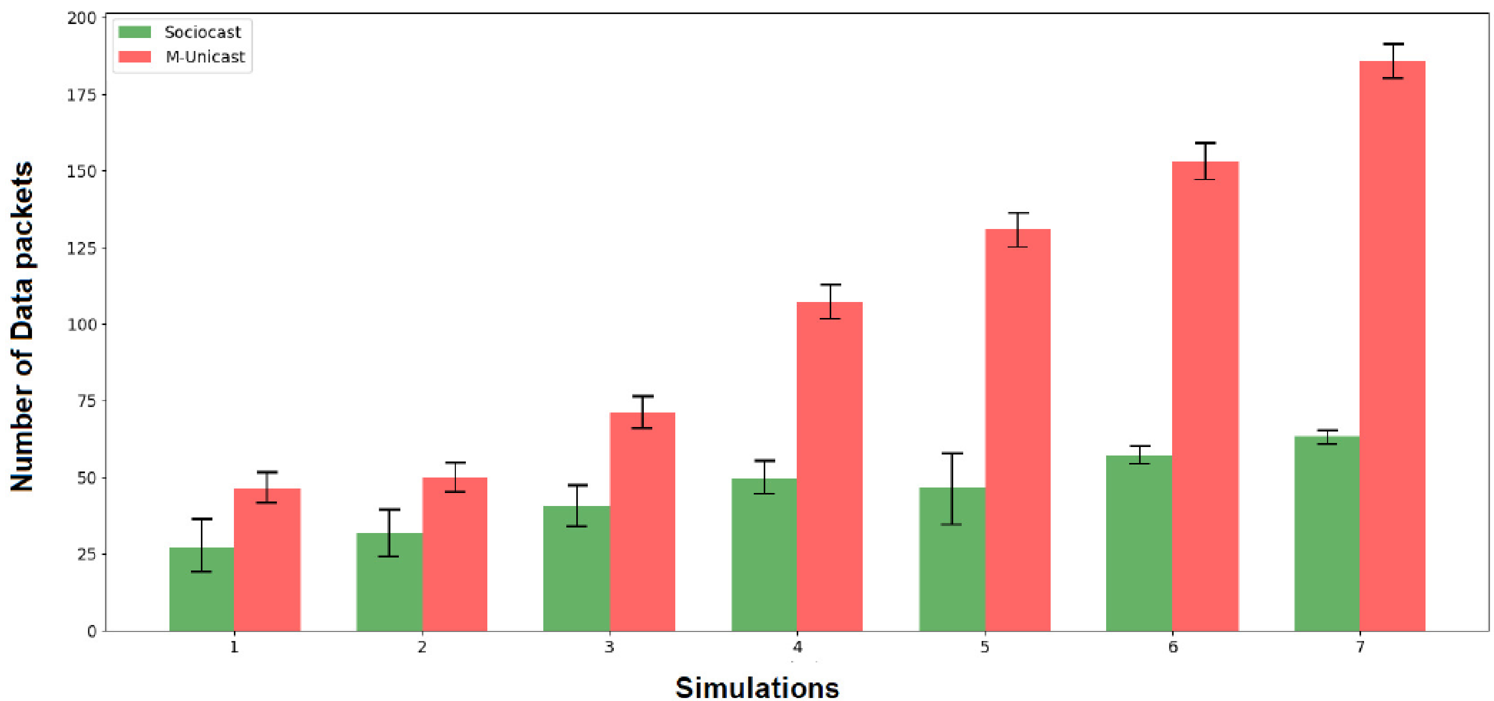
(a) Sociocast group creation latency

Proof-of-concept initial tests



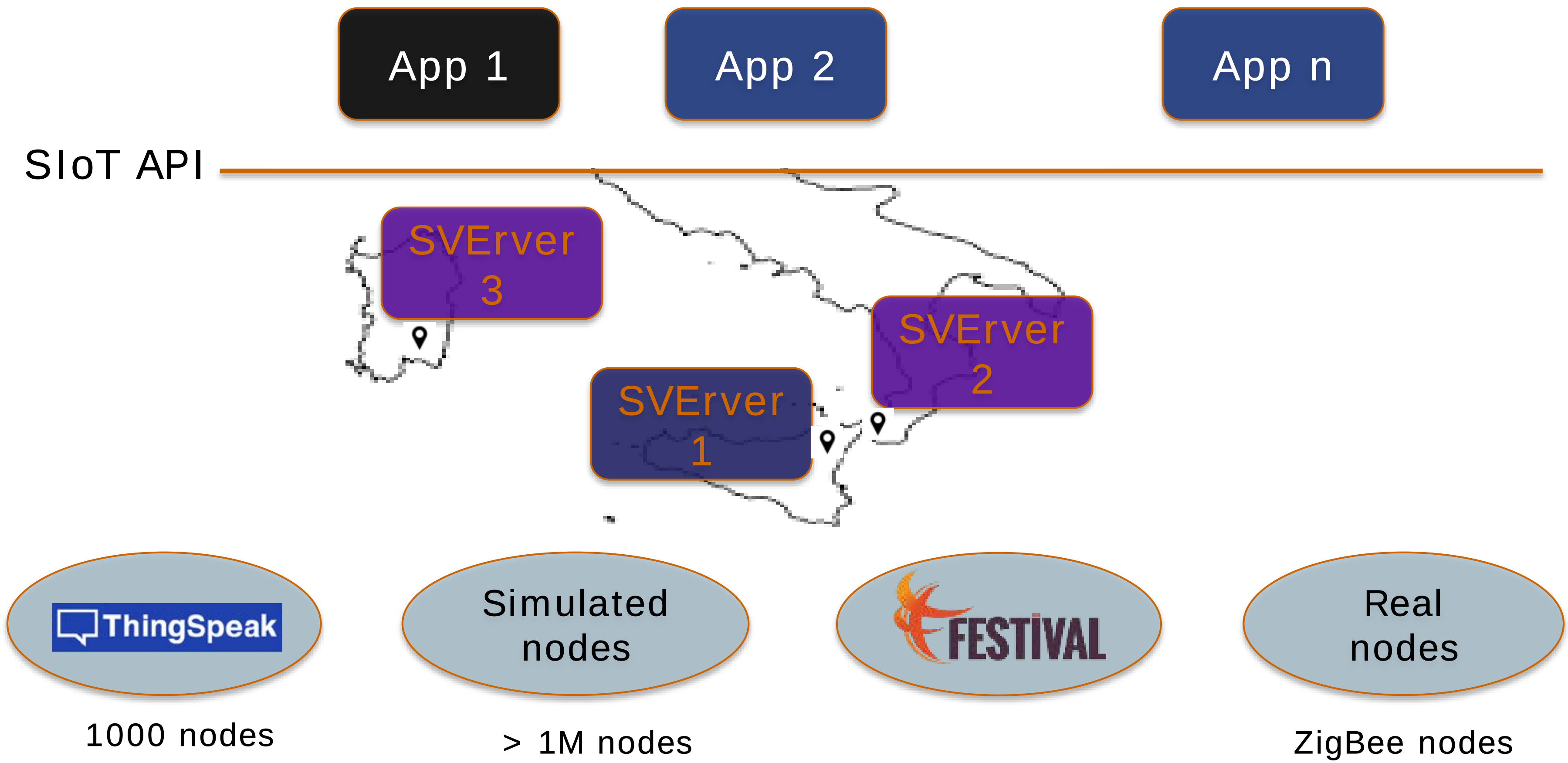
(b) OF signaling packets to create the sociocast group

Proof-of-concept initial tests



(c) Exchanged Sociocast packets in the topology

Current deployment



❑ Future research directions

Conclusions

- We have designed and realized a complete framework that exploits the SIoT concept to overcome the Internet of Platform impasse
- We have designed a group communication method over this framework
- Not just a research idea…
- You are invited to experiment you research ideas with $SIoT^2$

Open research issues

- *Relationship Manager:*
  - Need for solutions able to **find relevant relationships in short time intervals** (reasonable computing effort)
- *Placement of SVEs:*
  - Performance improves if SVEs that establish relationships and interact with each other **run in the same SVErver** → Optimization
- *Data plane:*
  - Need for a **data plane** enabling data transfer according to Sociocast primitive. → A non-disruptive transition from existing protocols is preferable.
- *Sociocast programming:*
  - Need for **suitable socket APIs** (Application Programming Interfaces) with relevant socket options to enable hosts to join Sociocast groups
- *Energy cost:*
  - Devices need to run additional operations → **Energy consumption** → Optimize the process
- *Sustainability*
  - Identify viable **business models**
- *Performance analysis:*
  - Need for proving Sociocast **performance** against changes in network topologies, user mobility profiles, social graph.
- *Security & confidentiality:*
  - to assure that exchange of information relevant to SVE is **secure and controllable** by the device's owner

References

SVE latest *public* description

- L. Atzori, C. Campolo, B. Da, R. Girau, A. Iera, G. Morabito, S. Quattropani, "Enhancing Identifier/Locator Splitting through Social Internet of Things", *IEEE IoT Journal*, 2018. doi: 10.1109/JIOT.2018.2877756

Sociocast

- Luigi Atzori, Antonio Iera, Giacomo Morabito (2019), "Sociocast: A New Network Primitive for IoT", IEEE Communications Magazine, June 2019, Vol. 57, n. 6, doi: 10.1109/MCOM.2019.1800917
- L. Atzori, C. Campolo, A. Iera, G. Milotta, G. Morabito, S. Quattropani, Sociocast: Design, implementation and experimentation of a new communication method for the Future Internet, *World Forum on IoT, WF-IoT 2019*.

Thank you for your attention!

Questions:

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