



Mobile and 5G Research

**Professor Sasu Tarkoma, Head of Department
NODES Research Group
19 June 2017**

The logo of the University of Helsinki, featuring a stylized white flame or flower-like shape with a central square, flanked by two smaller squares above and below.

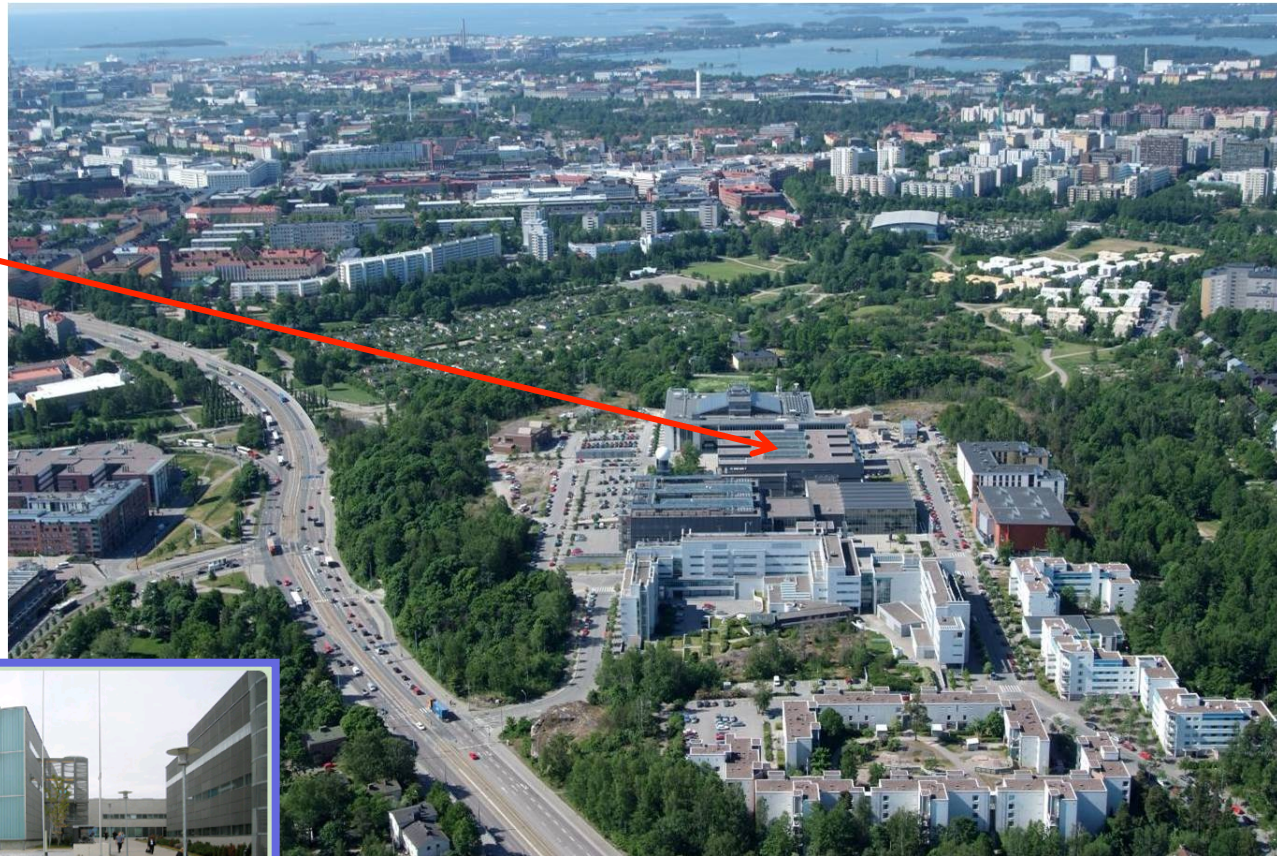
UNIVERSITY OF HELSINKI

UNIVERSITY OF HELSINKI

Faculty of Science at Kumpula Campus

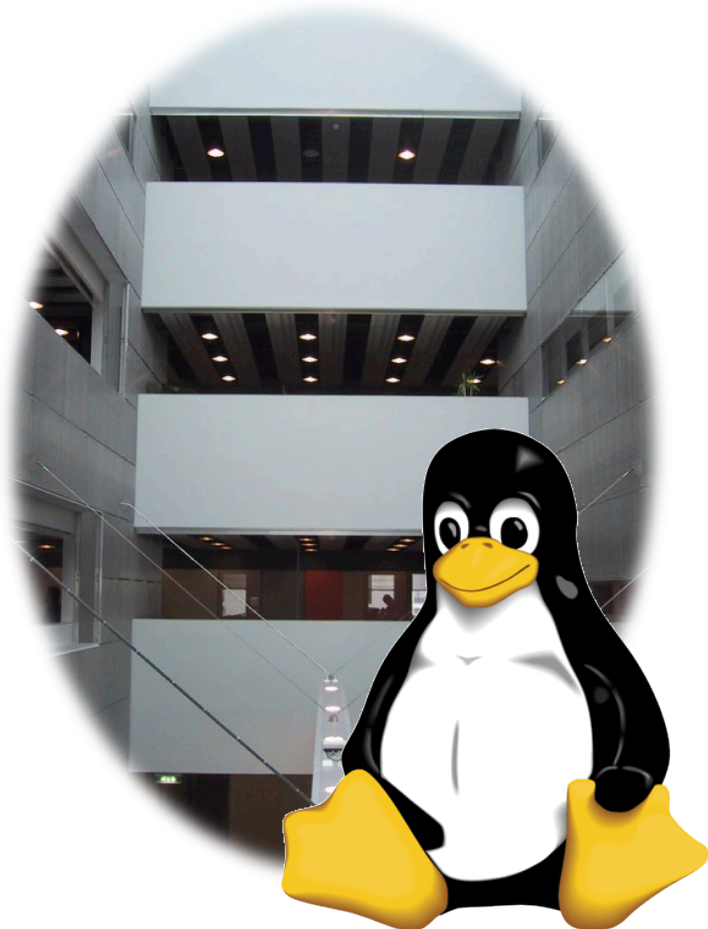
Departments

- Chemistry
- Computer science
- Geosciences and Geography
- Mathematics and Statistics
- Physics



50 Years of Excellence

- **Department of Computer Science**
- Leading institution in Computer Science in Finland
 - #1 in Finland in QS Ranking 2017
 - #1 in Nordic Countries and overall #69 in Times Higher Education 2017
- **Core CS and Data Science**
 - Algorithms, Data Analytics and Machine Learning
 - Software Systems
 - Networking and Services (NODES)
 - Bioinformatics



data mining
data analysis
statistics
machine learning
distributed computing

natural sciences and engineering
life sciences and medicine
humanities, social sciences
pedagogics, economics

Methods

Applications

HiDATA

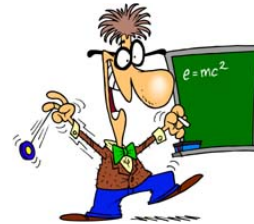
Data Science



Research
results



Education
of experts



Innovations



Information for
the general public

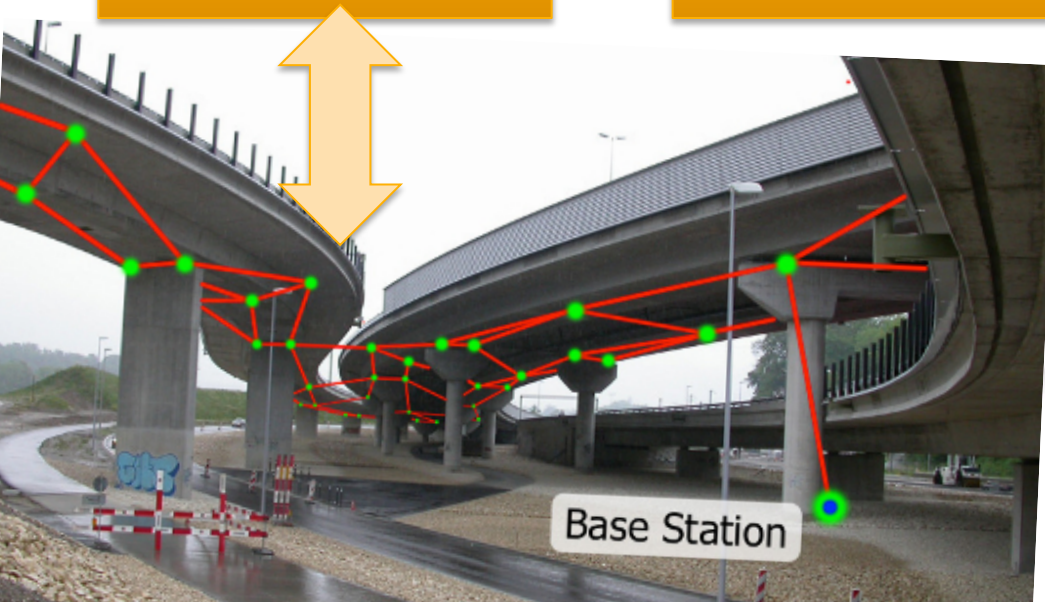
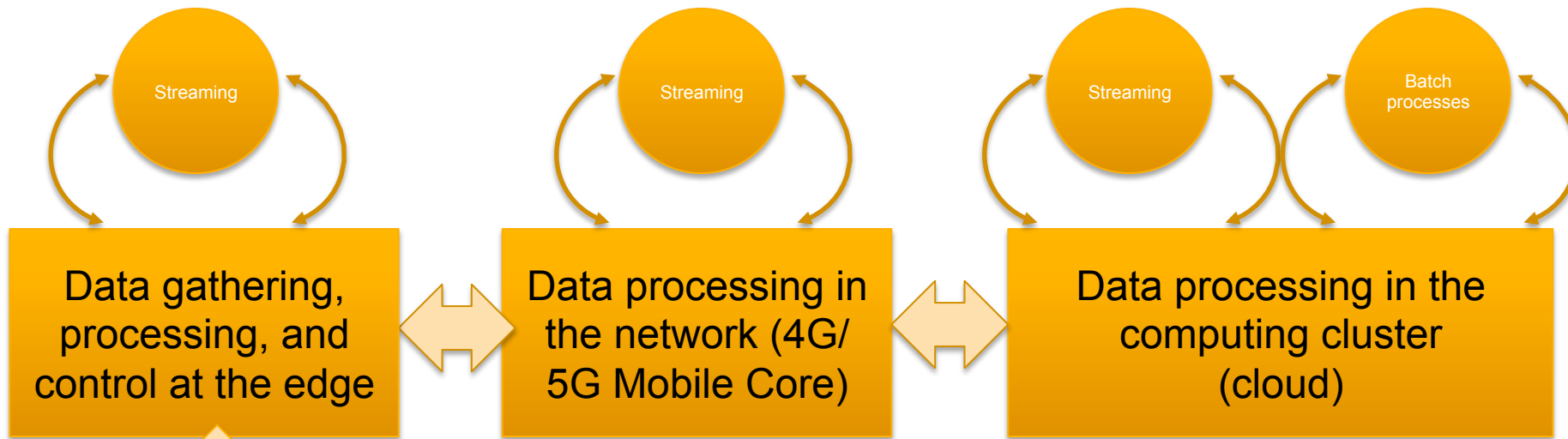


Current research topics include:

Digital services, IoT security and privacy, software-defined networks, Data Science, ...

Mobile Edge Computing

Big Data Frameworks



Mobile Research: Carat

Carat team (carat.cs.helsinki.fi)



Motivation



Battery
lifetime?

Risk level?



Many heterogeneous, active devices and many users with different intents. – What kind of behavior is **normal** or **typical**?

Introducing Carat

Carat is the **first system** to use the mobile device community to detect and correct energy problems

Our method for **diagnosing** energy anomalies uses the community to infer a specification (expected energy use), and we call deviation from that inferred specification an anomaly

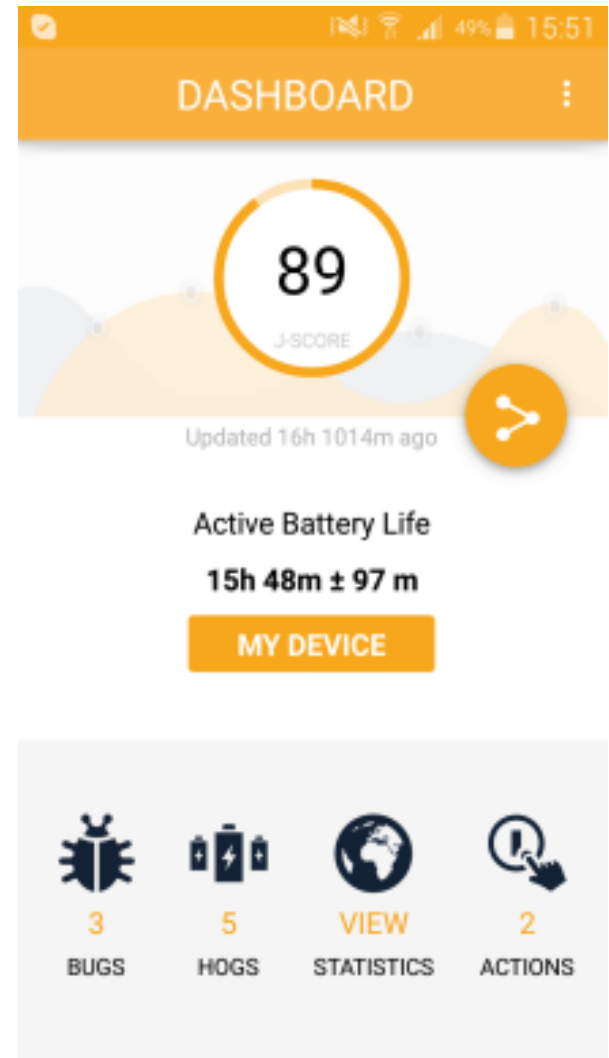
Carat

- Originated in UC Berkeley, in collaboration with University of Helsinki
- Mobile app for Android and iOS
- Currently over 850 000 users
- >2.5 TB of data, > 250 million measurements
- Research project with many directions
- <http://carat.cs.helsinki.fi>



What is Carat?

- Mobile app shows users advice:
“Kill Facebook for 16m ± 41s battery life”
- Energy **hogs** and **bugs**
- Tracks user's battery life average since installation
- Places users within community with a ranking called J-Score



Comment

36



Like

1k



Tweet



Share

309



171

Carat: The Brilliant App That Increases Your Battery Life By Showing What Other Apps To Kill



JOSH CONSTINE

Thursday, June 14th, 2012

36 Comments



"Kill Pandora – Expected Battery Life Improvement: 1 hour 50 minutes" This is what you'll learn from **Carat**, an incredibly useful free **new iOS** and **Android app** that's the first to give you personalized mobile battery life-saving recommendations.

Carat quietly takes measurements from you device, does some math, combines it with other people's anonymized data, and sends back tips on if you should update your OS, kill or restart apps, and how many more minutes of tablet or phone fiddling you'll gain.

As battery tech is expected to improve slowly, some say increasing life just 5% a year, and as we get faster processors, more powerful apps, and brighter screens, everyone could use a Carat in their pocket.

Suddenly...

t By 'o Kill

36 Comments

Life Improvement: 1 hour
from **Carat**, an
Android app that's the
battery life-saving

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Suddenly...



t
By
'o Kill

Free Carat app finds 'energy hogs,' 'energy bugs' on iOS or Android devices

ANDROID | JUNE 14, 2012 | BY: MICHAEL SANTO

4 Likes, 2 Tweets, 0 +1s, 0 Stumbles, 0 Emails

Get Tech Gear alerts!



Su



Carat

Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM



Carrier 1:44 PM

Your J-Score: **70** ⓘ
(Updated 15s ago)

Average Battery Life: **11h 7m 32s**

OS version: **5.1** ⓘ

device model: **Simulator** ⓘ

running apps: [View Process List](#) ⓘ

memory used: ⓘ

memory active: ⓘ

amplab
UC BERKELEY

Carrier 11:35 PM

To improve battery life:

- Restart Evernote
Expected improvement: 4
- Upgrade the Operating System
Expected improvement:
- Help Spread the Word!
Expected improvement:

(Updated 1d 4h 27m 1s)

Actions My Device Hog Report Bug Report About



Carrier 1:44 PM

Your J-Score: **70** ⓘ
(Updated 15s ago)

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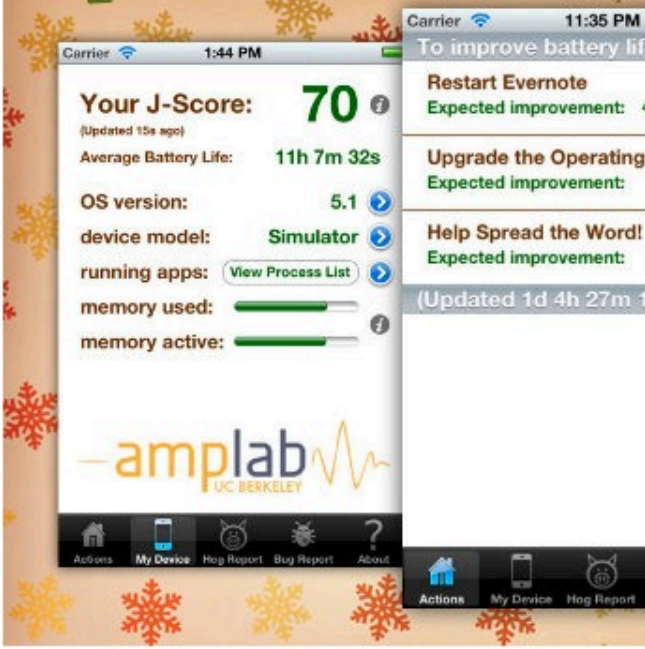
Carat



Su

Carat: Extend Your Phone's Battery Life

LESLIE HORN JUNE 19, 2012 2:00 PM



Topic: iPhone

iOS and Android app helps you get more from your battery

Summary: Carat has been developed by a team of scientists from the UC Berkeley electrical engineering and computer science department's Algorithms, Machines, and People Laboratory (AMP Lab).



By [Adrian Kingsley-Hughes](#) for [Hardware 2.0](#) | June 15, 2012 -- Updated 10:21 GMT (03:21 PDT)

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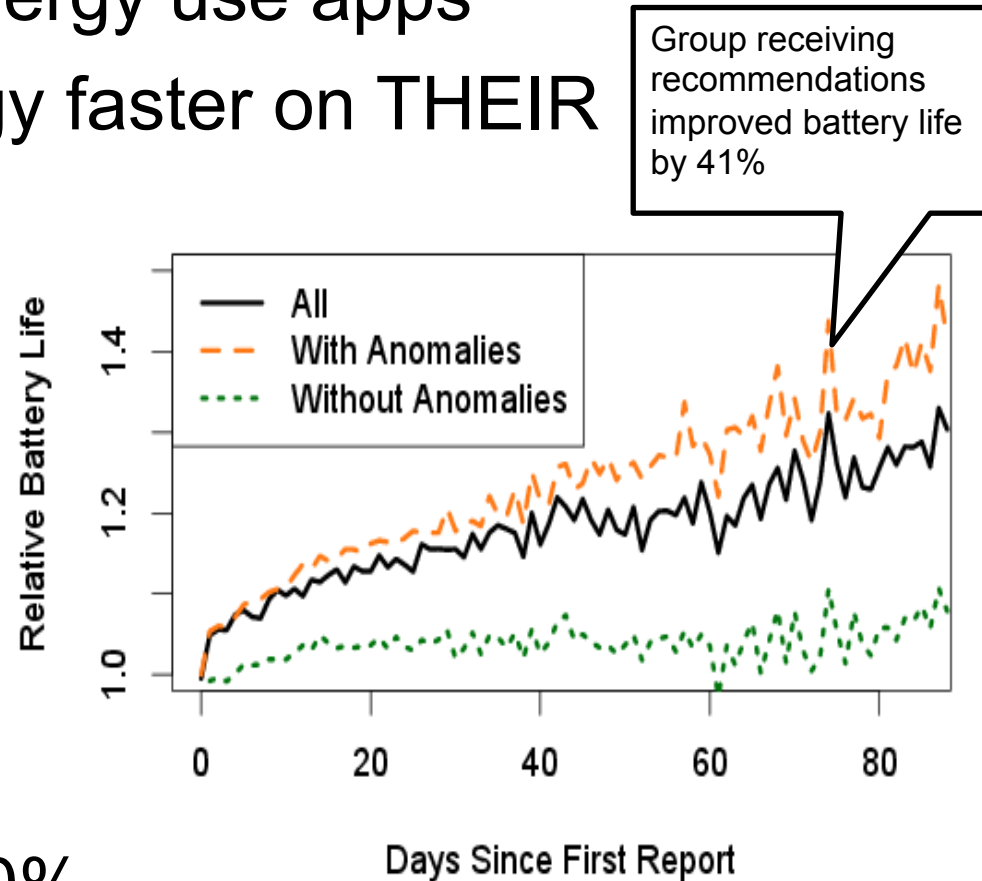
[Follow @the_pc_doc](#)



What is Carat?

- Users see Hogs, high energy use apps
- And Bugs that use energy faster on THEIR device than on others
- Users with these issues quickly see battery life benefits once they are addressed

- Average improvement 20%
- Those with energy anomalies can improve 41%



The Carat project: System

Smartphones
with Carat
Applications



Load
Balancer



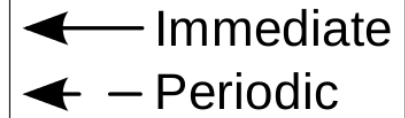
Carat
Servers



Large
Synchronized
Storage



Carat Analysis on a
Spark Computing Cluster

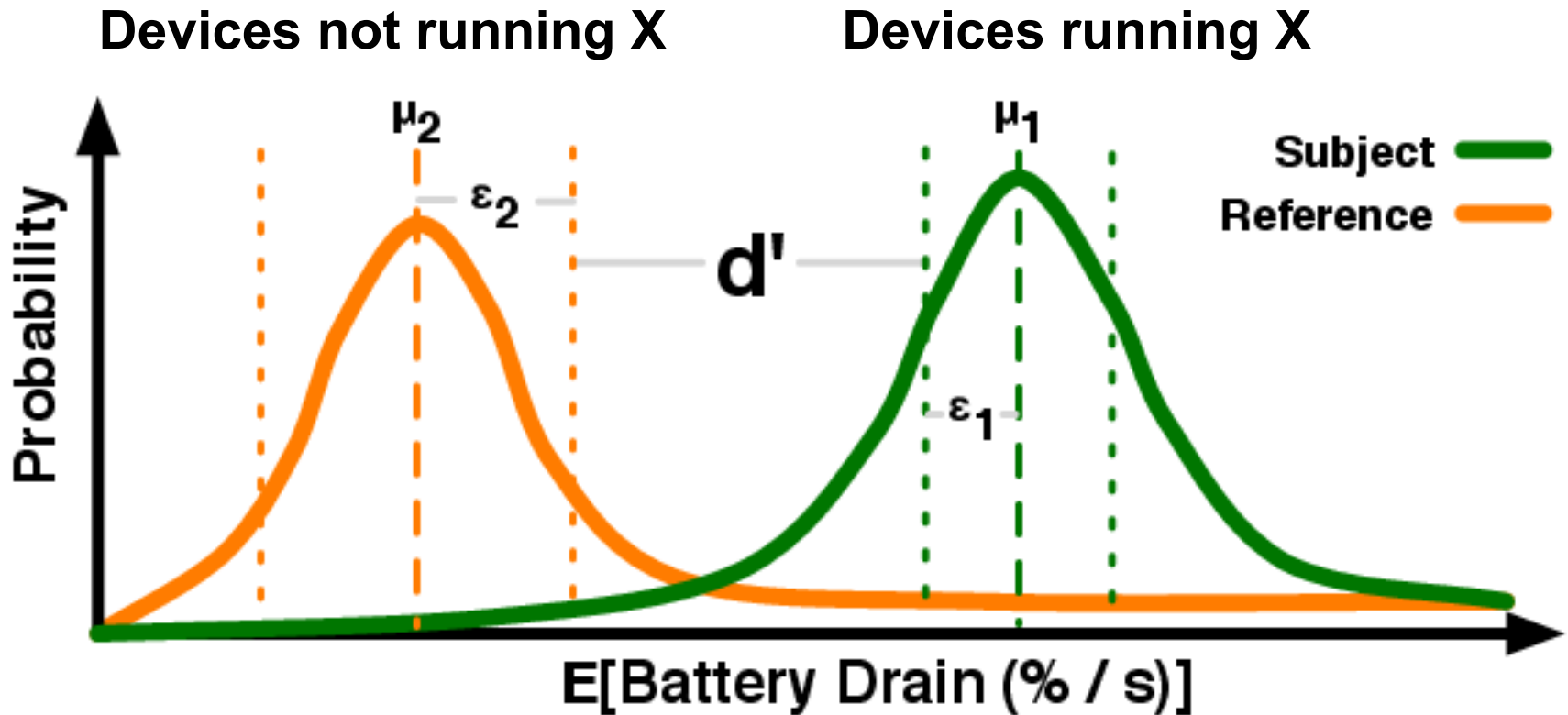


The Data Analysis

- Samples are combined to obtain energy drain probability distributions (with features)
 - Users, Apps, App and User pairs, OS versions, Device models
- Distributions are compared using the distance between their 95% confidence interval error bars
 - If a distribution has a positive distance from another and a higher mean, it is a:
 - **Hog** (for an app vs the distribution for other apps)
 - **Bug** (for app & user combination vs other users of the same app)

Hogs and Bugs

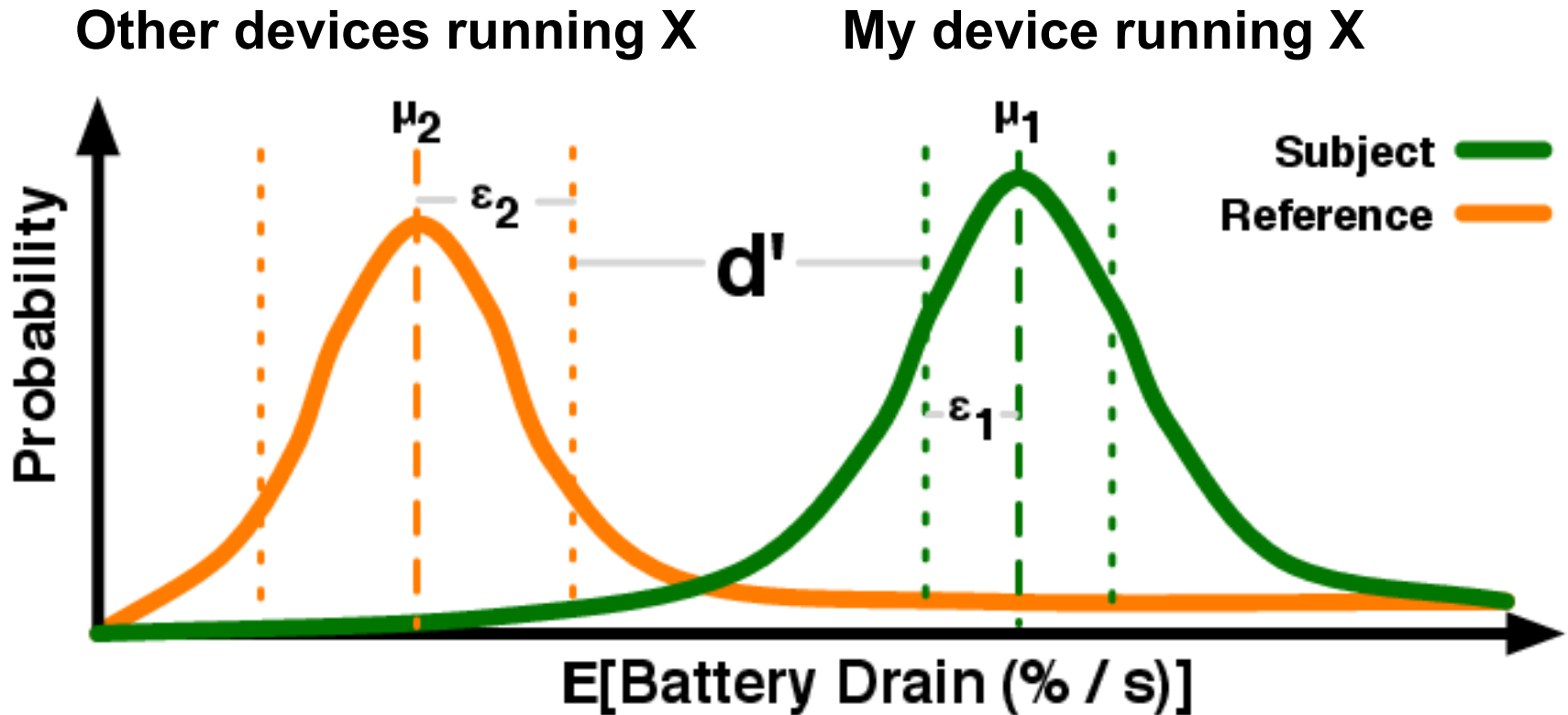
HOGS



...

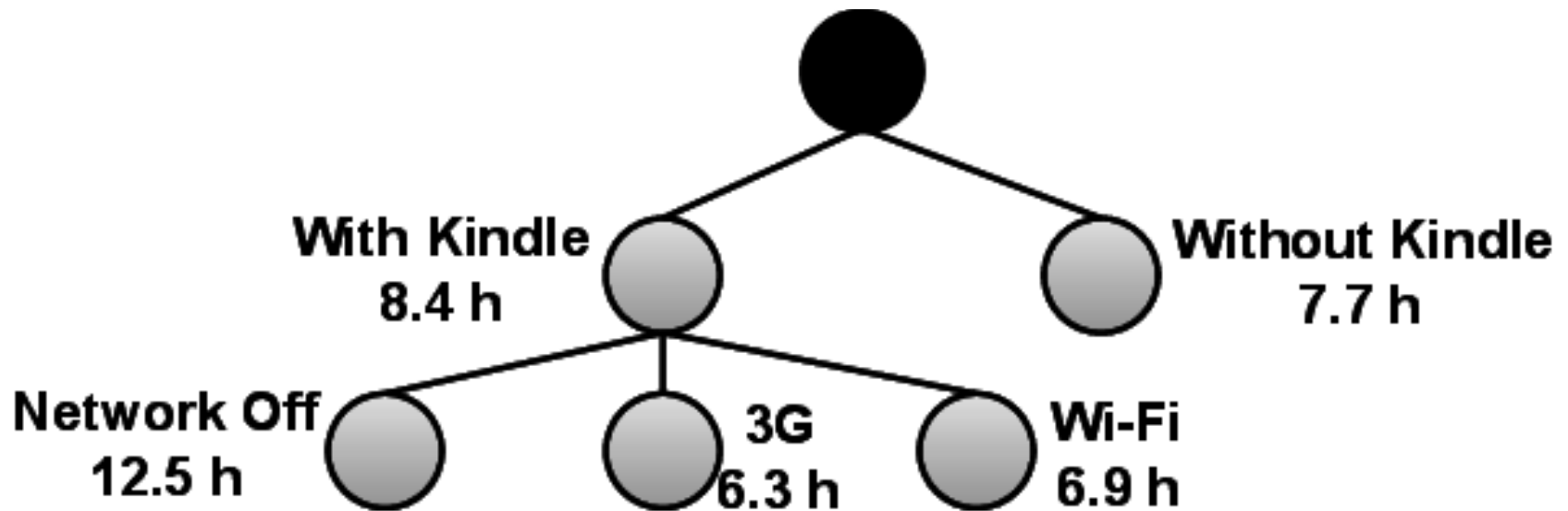
Hogs and Bugs

BUGS



...

Example: The Kindle WhisperSync bug



The decision tree allows “what-if” analysis and the generation of recommendations

The PADS Project

The PADS project will develop new privacy enhancing algorithms and methods for **Data Science**

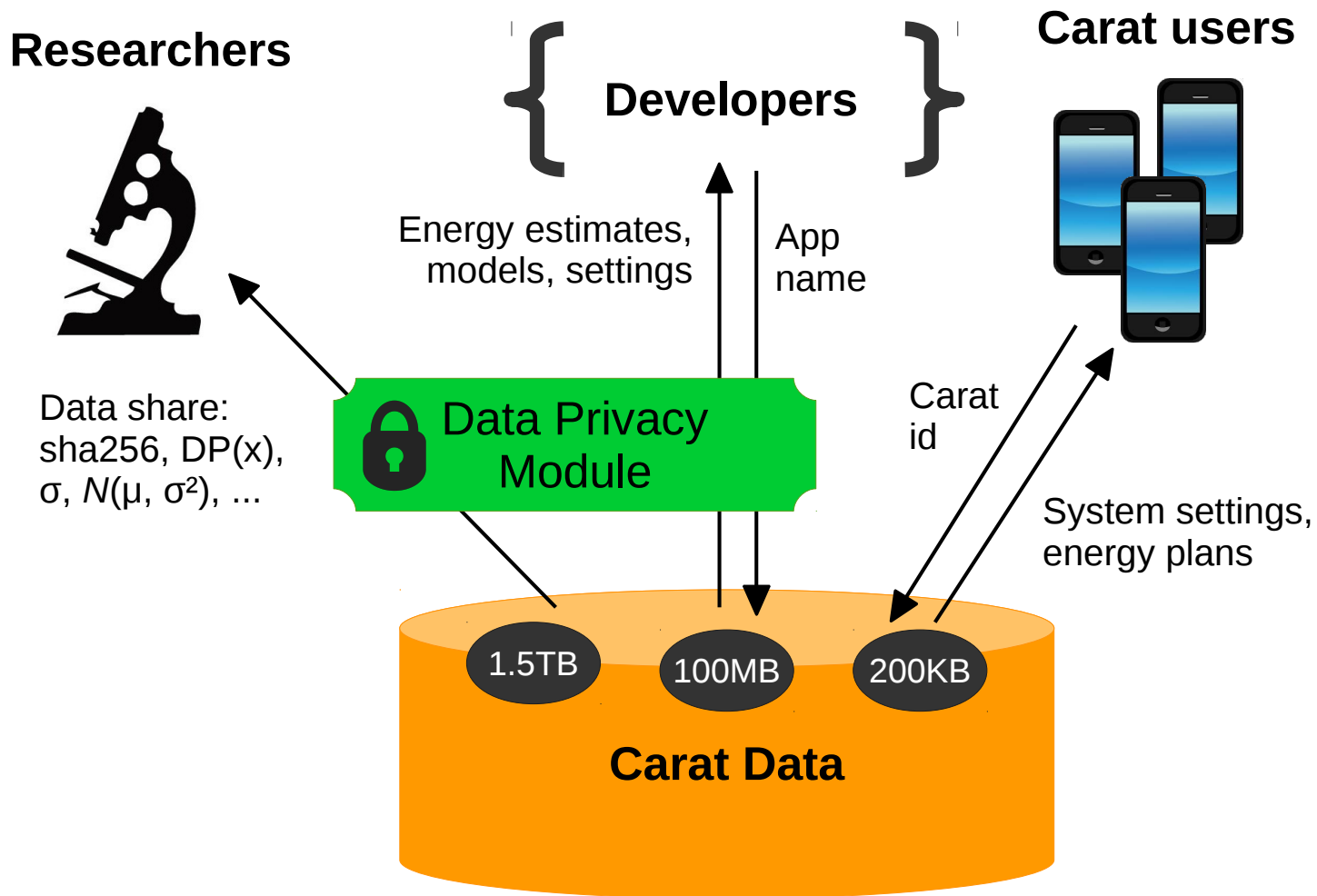
Two methodological goals

- Develop the algorithmic framework for privacy-aware predictive modelling, and
- Scalable implementation of the framework

Two key use cases

- Large-scale genome data processing and sharing for personalized medicine, and
- Mobile and environmental sensing

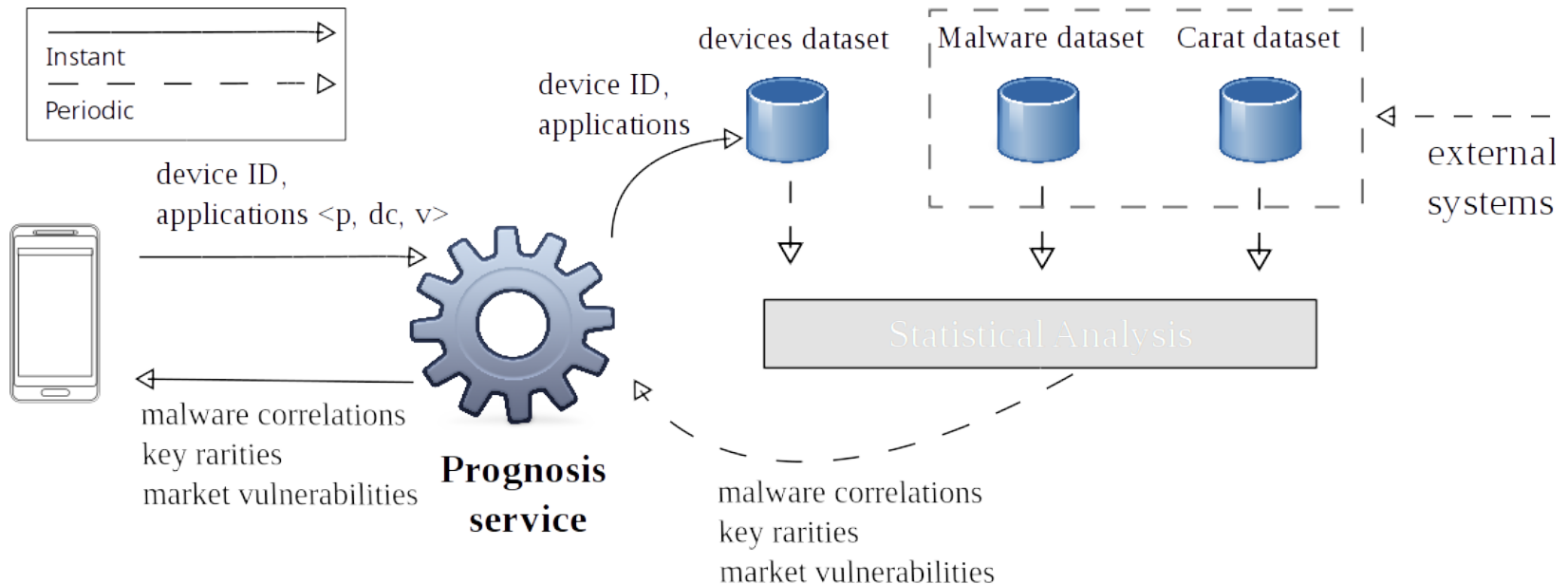
PADS Sensing SDK Overview



An Early Warning System for Malware

A lightweight technique for identifying devices at risk
By looking at applications that occur with malware, it is possible to predict infection 5x better than choosing devices at random

- Useful for administrators, organisations (**Bring Your Own Device** scenario)

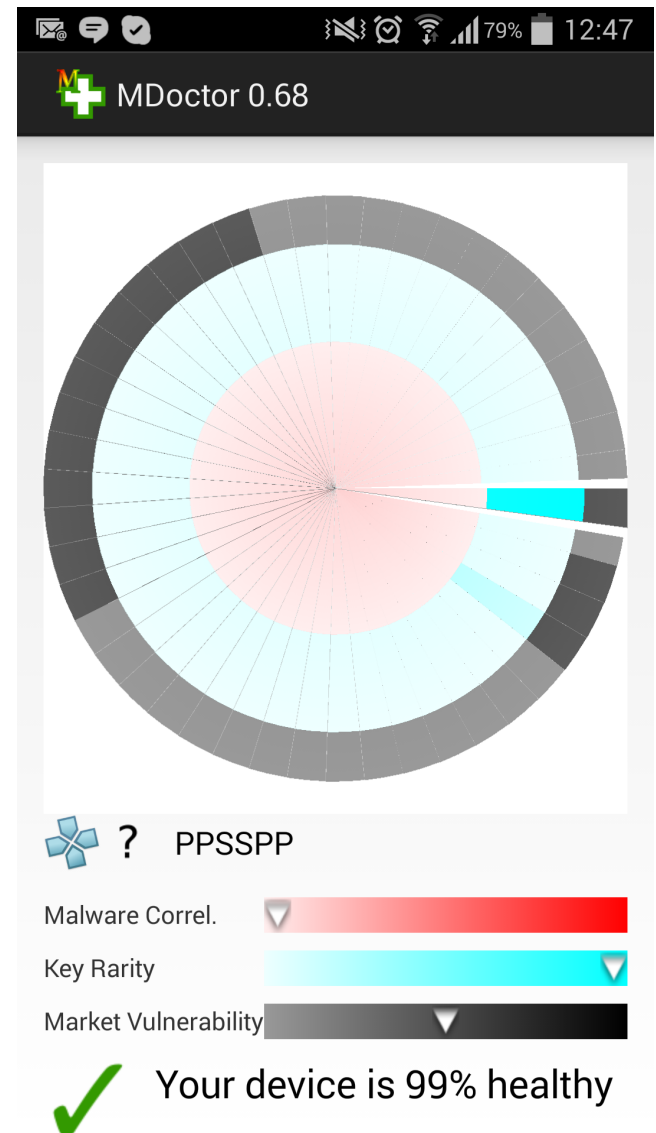


MDoctor: Increasing Awareness of Infection Vulnerability

MDoctor shows status of applications according to a malware dataset

Infection vulnerability can be seen from device health

Three metrics for application analysis: malware correlation, key rarity, and market vulnerability



5G Research



NOKIA CENTER FOR ADVANCED RESEARCH (NCAR)

The Nokia logo, consisting of the word "NOKIA" in a bold, blue, sans-serif font.

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

The logo "A?", where the letter "A" is black and the question mark is yellow.

NCAR was launched in April 2016 and is a joint research center with University of Helsinki, Aalto University, and Nokia.

To foster **wider cooperation** between the universities and Nokia to enable **cross-unit research** delivering high quality results: thesis, publications, holistic concepts and demos.

A background pattern of blue, 3D-looking geometric shapes, possibly representing a soundproofing foam or a crystalline structure, with varying shades of blue and white highlights.

ncar.cs.helsinki.fi

5G Test Network Finland

5G Radio Network

5G Core Network

Business and Regulation

Internet of Things

Network Functions Virtualization

Network Management

New Spectrum and Sharing Methods

Quality of Service/Experience

Software Defined Networking



EU

5G PPP / H2020, CELTIC+

ASIA

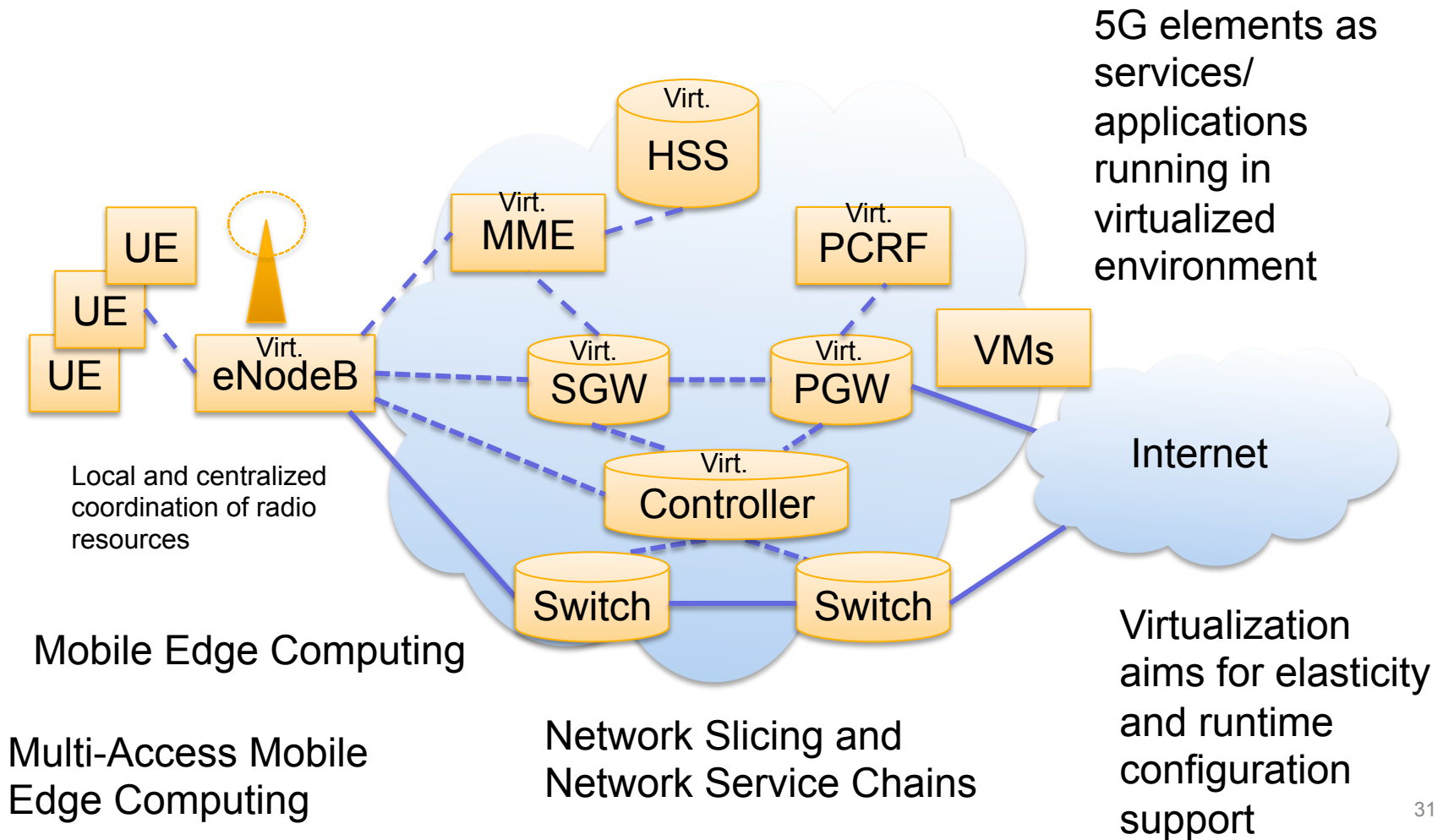
NSFC-FINNISH ACADEMY,
SINO-FINLAND ALLIANCE

USA

WIFIUS PROGRAM

5gtnf.fi

Starting point in 2014: LTE RAN and EPC with SDN and Cloud



Scaling Mobile Networks

5G is expected to support diverse use cases

Why current LTE networks cannot meet these demands?

Telephony Centric – IP traffic an afterthought

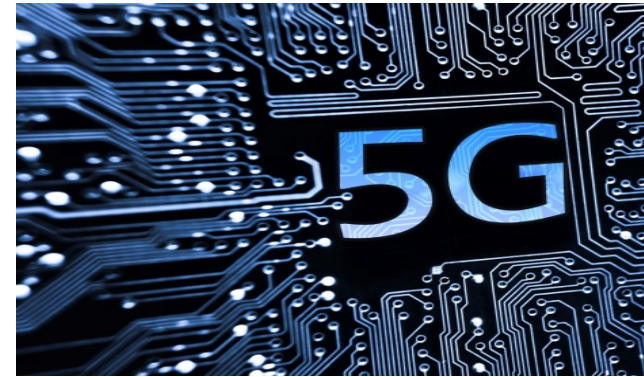
Convolved Control and Data Plane

Solutions

Move functionality to the Edge

Move functionality to the Cloud (NFV)

Network slicing



How do we modularize and refactor the network to meet the use case specific requirements?

Network Refactoring

Three steps:

1. Identifying the **roles** of the network functions
2. Splitting each network function into **modules**, creating one module for each role of the network function. For each module, we identify the requirements of a physical device instantiating that module.
3. Changing the **mapping** between physical devices and modules depending on the requirements (cost, latency, security, ...) from the network.

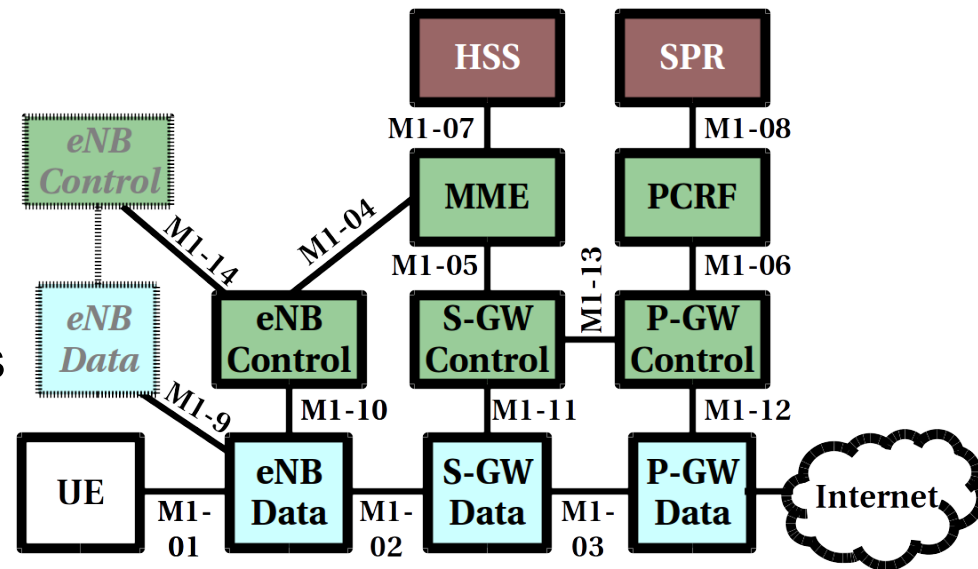
LTE control plane example:

Modularize architecture

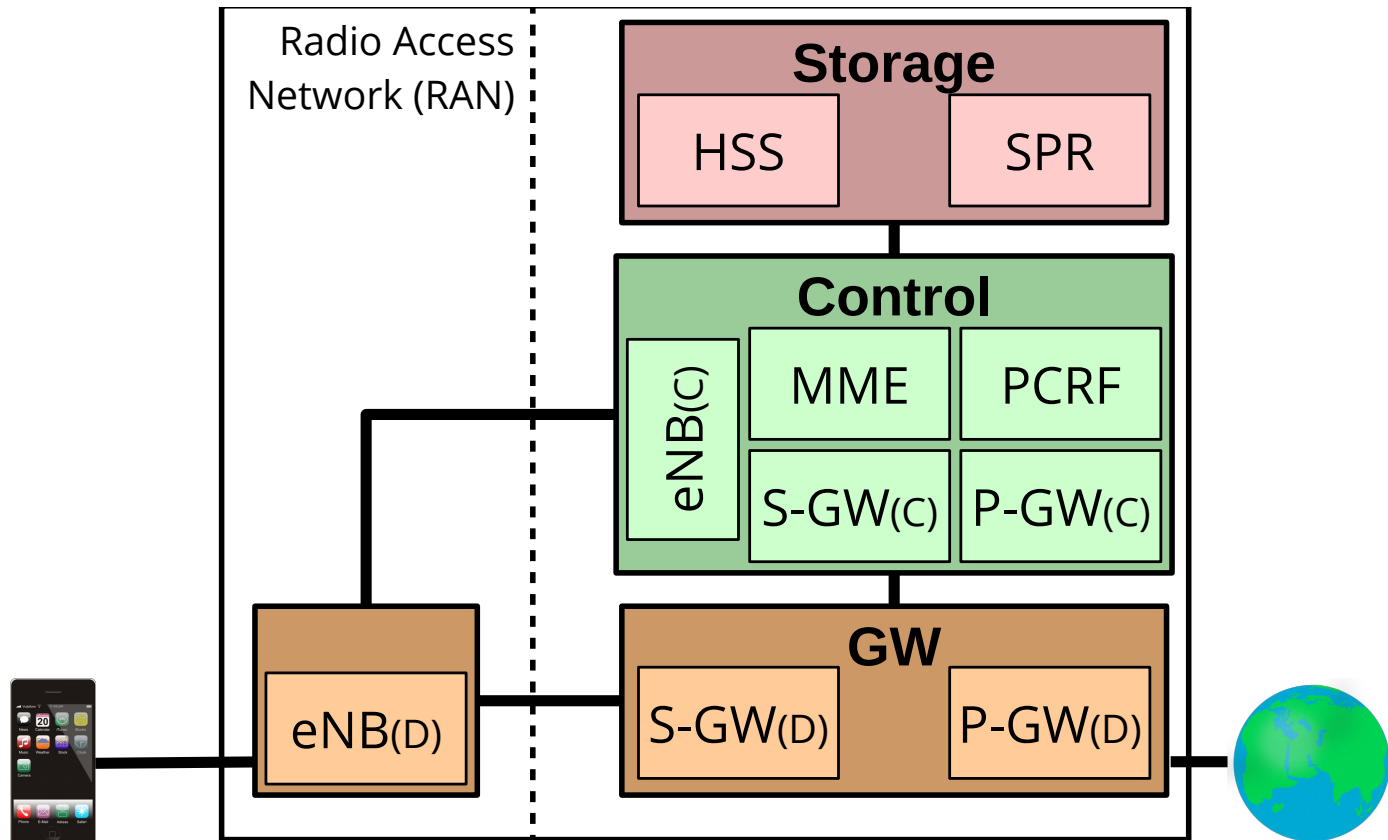
Identify **state variables**

Study **signals** between functions

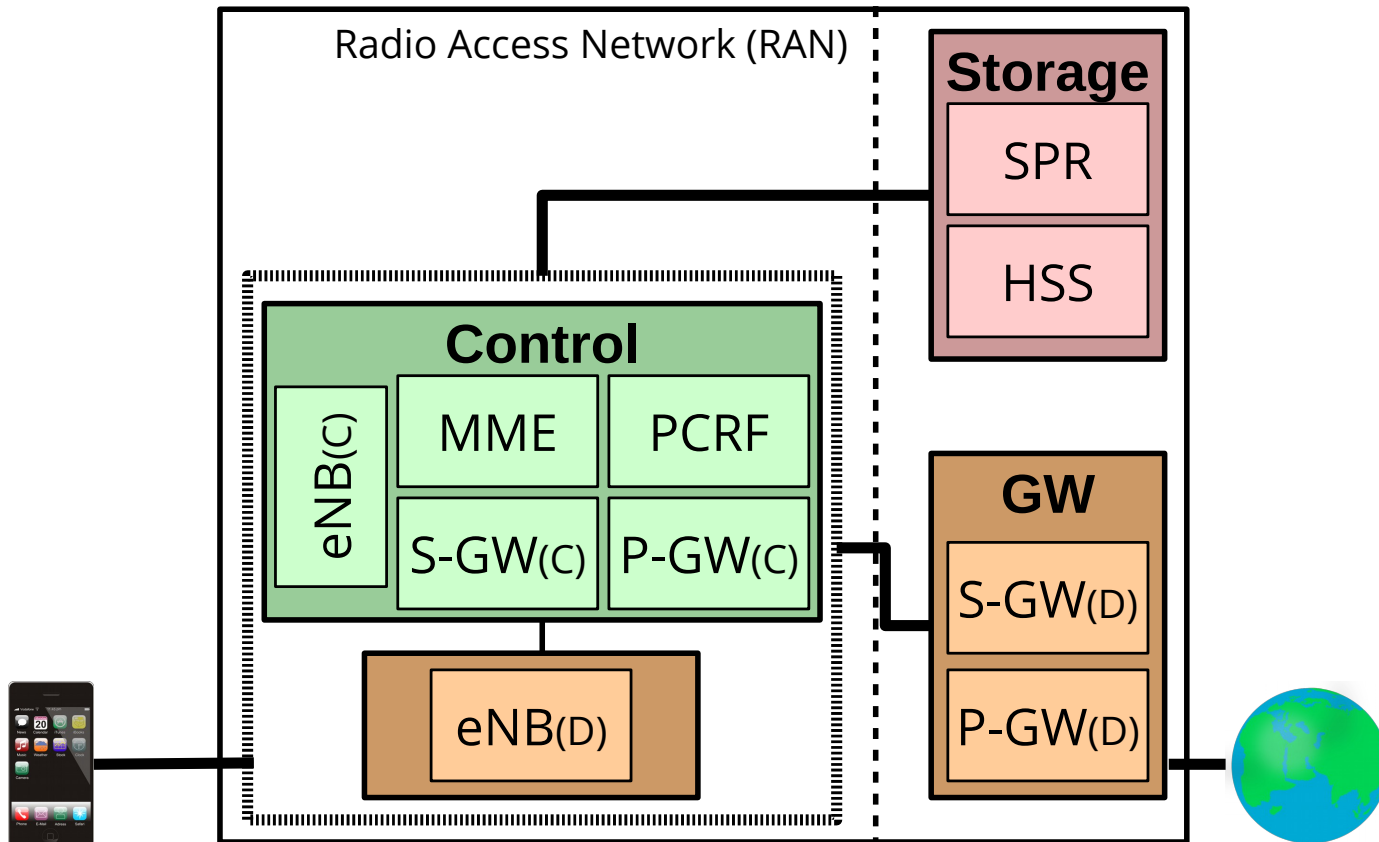
Combine modules



Refactoring: Thin Edge



Refactoring: Intelligent Edge



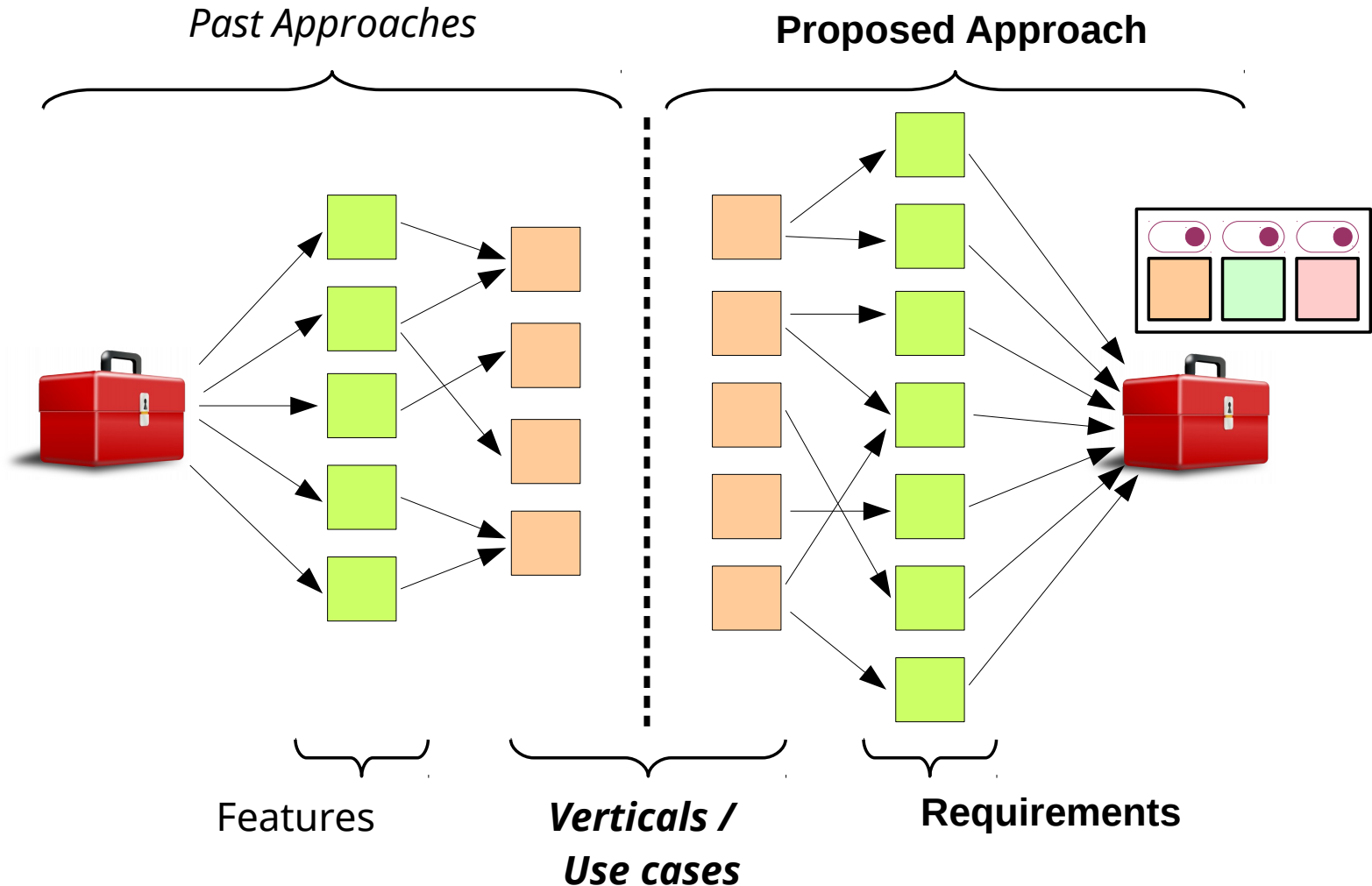
Refactoring Approach for Optimizing Mobile Networks

<i>Implementation</i>	<i>Total number of signals per event</i>				<i>Handover (S1H)</i>
	<i>Initial Attach</i>	<i>Active to Idle</i>	<i>Idle to Active (UE)</i>	<i>Idle to Active (Net)</i>	
<i>LTE (Baseline)</i>	35	6	13	17	22
<i>Thin Edge</i>	24	6	13	16	16
<i>Intelligent Edge</i>	17	3	10	12	12

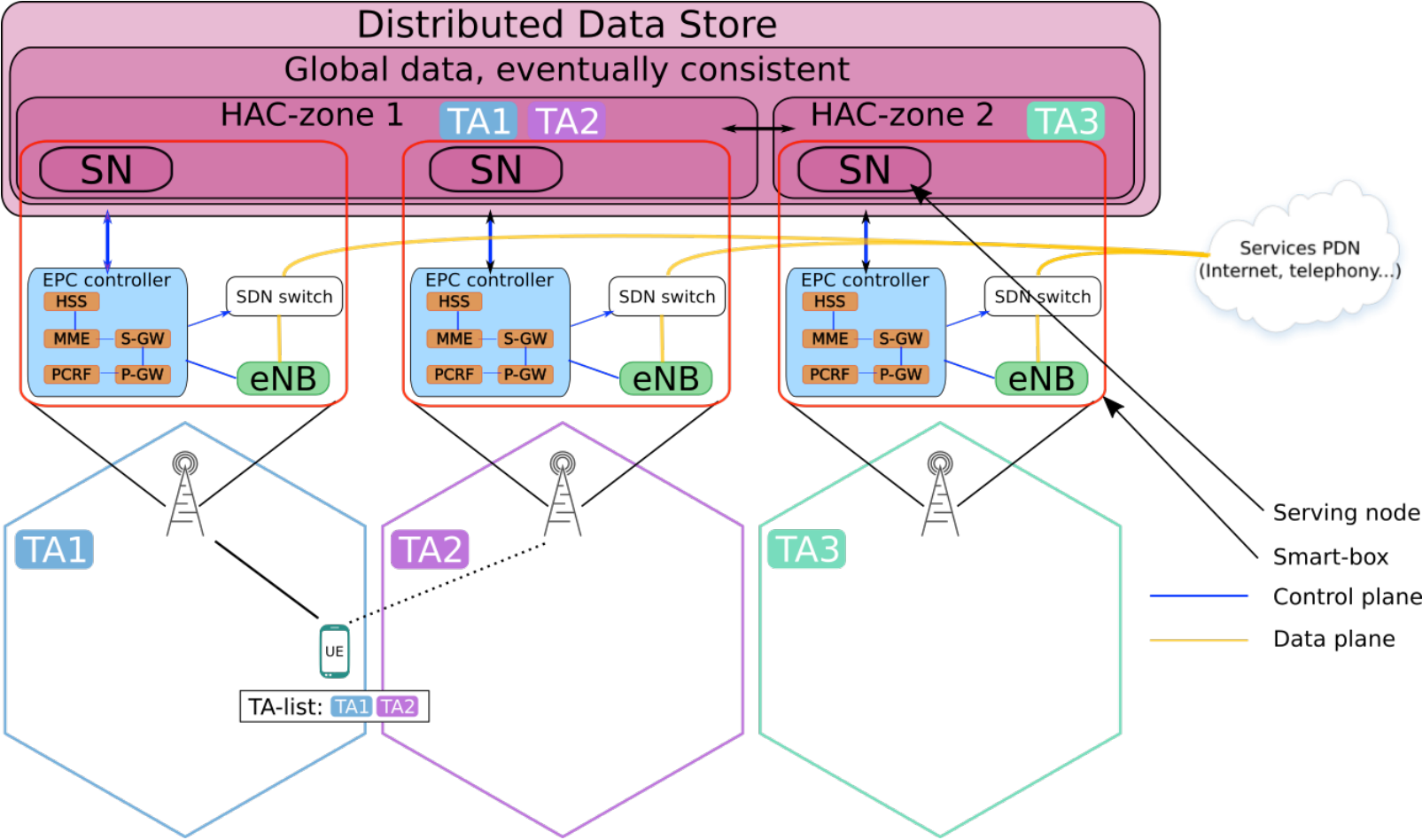
A Refactoring Approach for Optimizing Mobile Networks. Matteo Pozza, Ashwin Rao, Armir Bujari, Claudio Palazzi, Hannu Flinck, and Sasu Tarkoma. *In the Proceedings of IEEE ICC 2017*

Network in a Box

Create, scale, upgrade networks



Coreless Mobile Networks: A state management perspective



Implications

In theory, if the **data store** is the bottleneck, our results indicate the following numbers for a simulation of 15 eNB with Apache Geode:

Current deployments are seeing a maximum of 1000 UE / eNB
UE per area increases depending on configuration: ~84 - 740 x

5G prospects for the control plane scalability: 100 - 1000 x

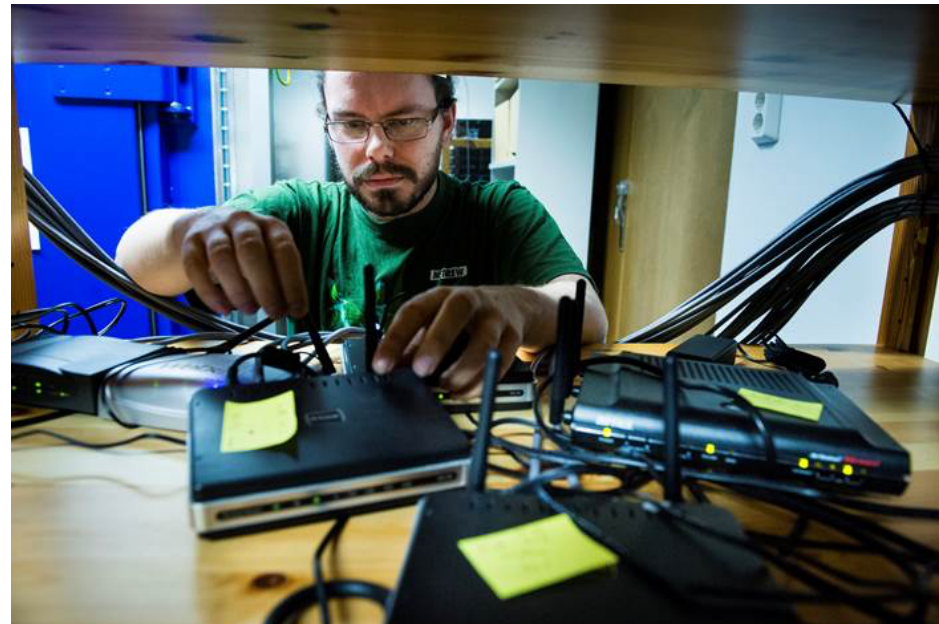
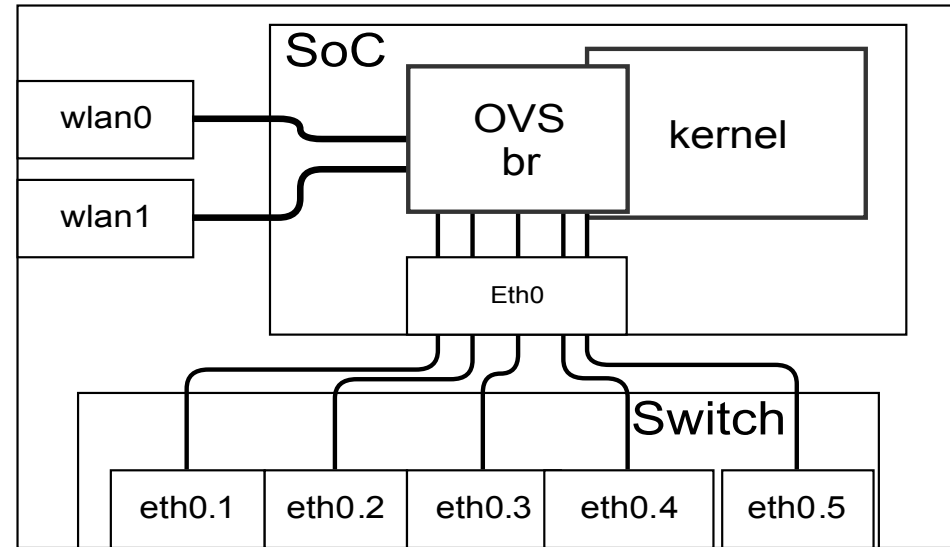
Off-the-Shelf Software-defined Wireless Networks

Open vSwitch (OVS) in base station
Use **Wireless Isolation** to force flows to OVS

Two approaches, Intelligent and Thin AP

Thin AP: Traffic is forced to flow through external host

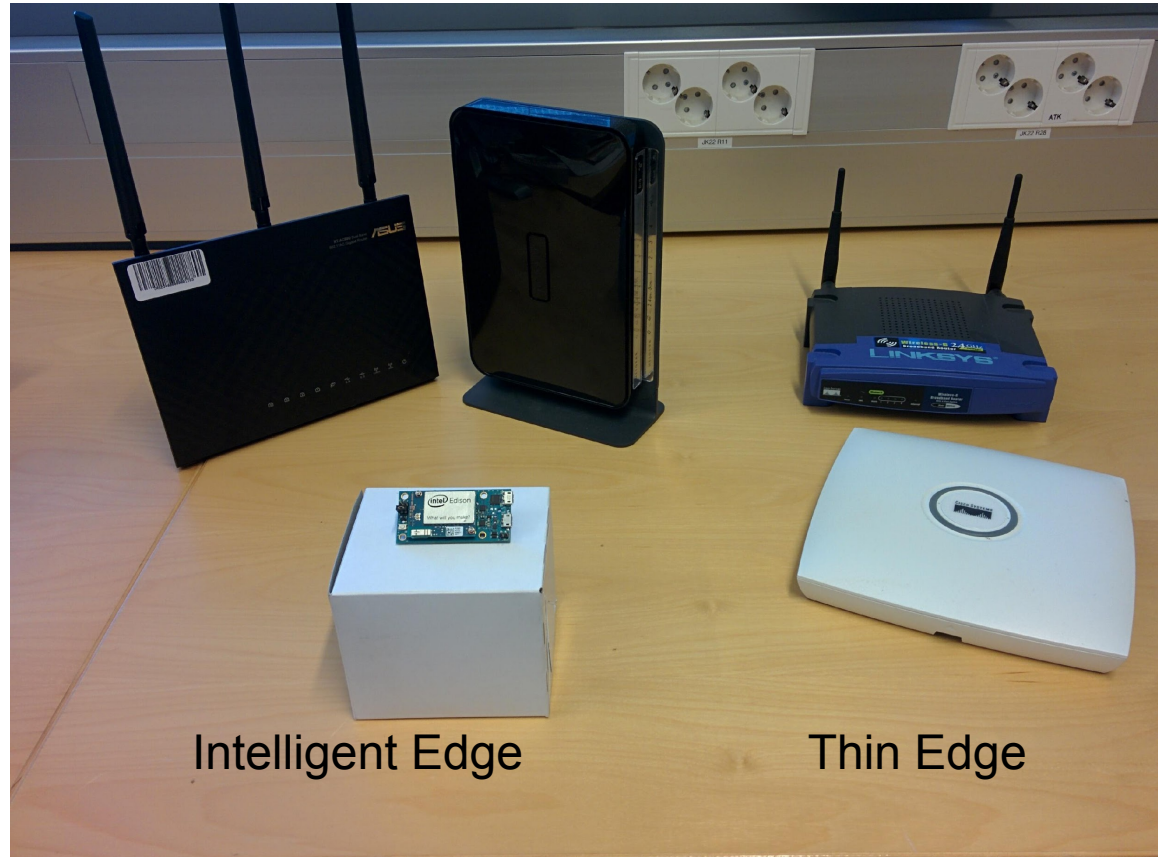
Intelligent AP: OVS in base station



Seppo Hätönen, Petri Savolainen, Ashwin Rao, Hannu Flinck, and Sasu Tarkoma.
ACM SIGCOMM 2016 demo.

Instructions:
<https://wiki.helsinki.fi/display/WiFiSDN/>

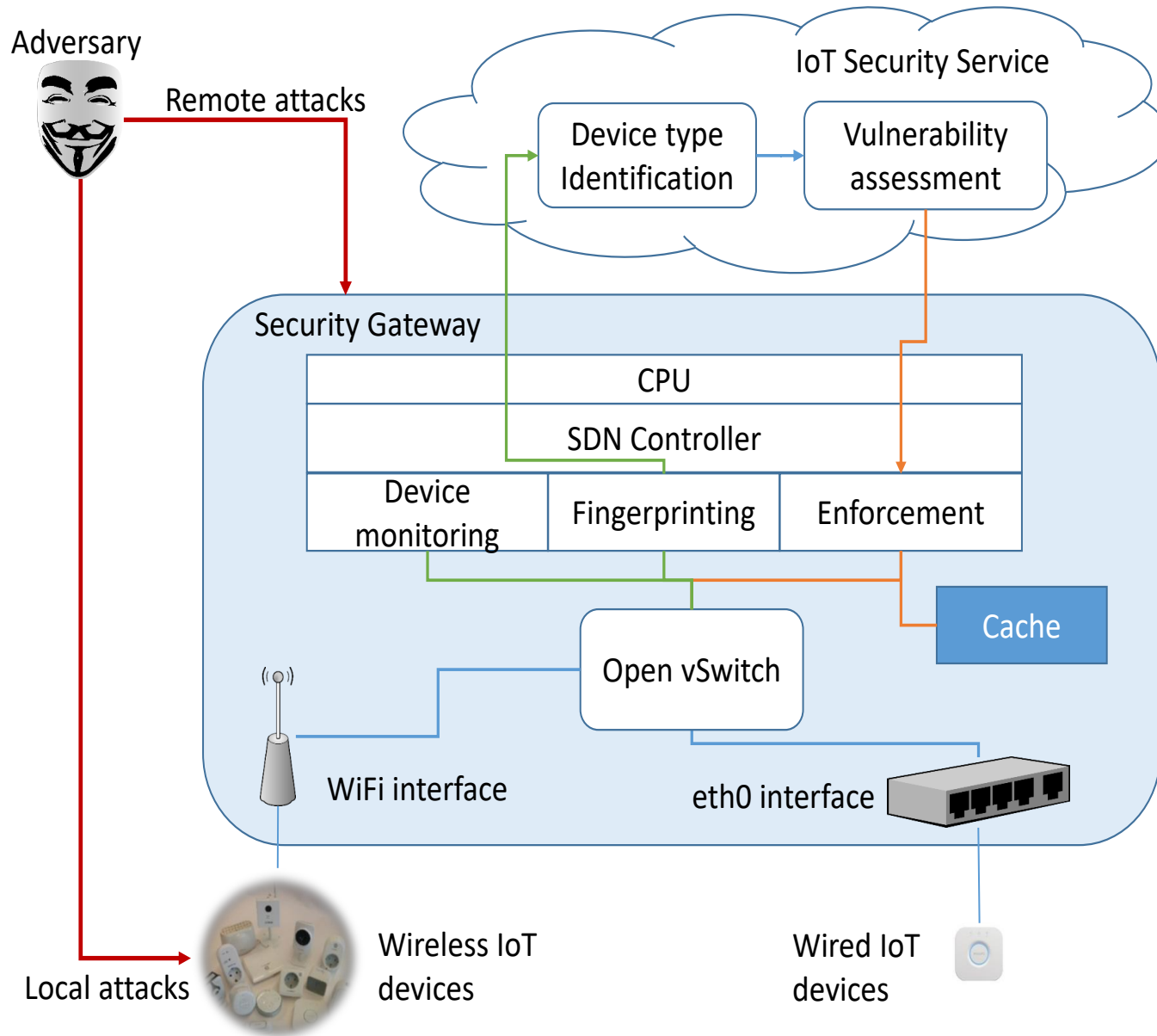
Deployable on Off-the-Shelf Devices



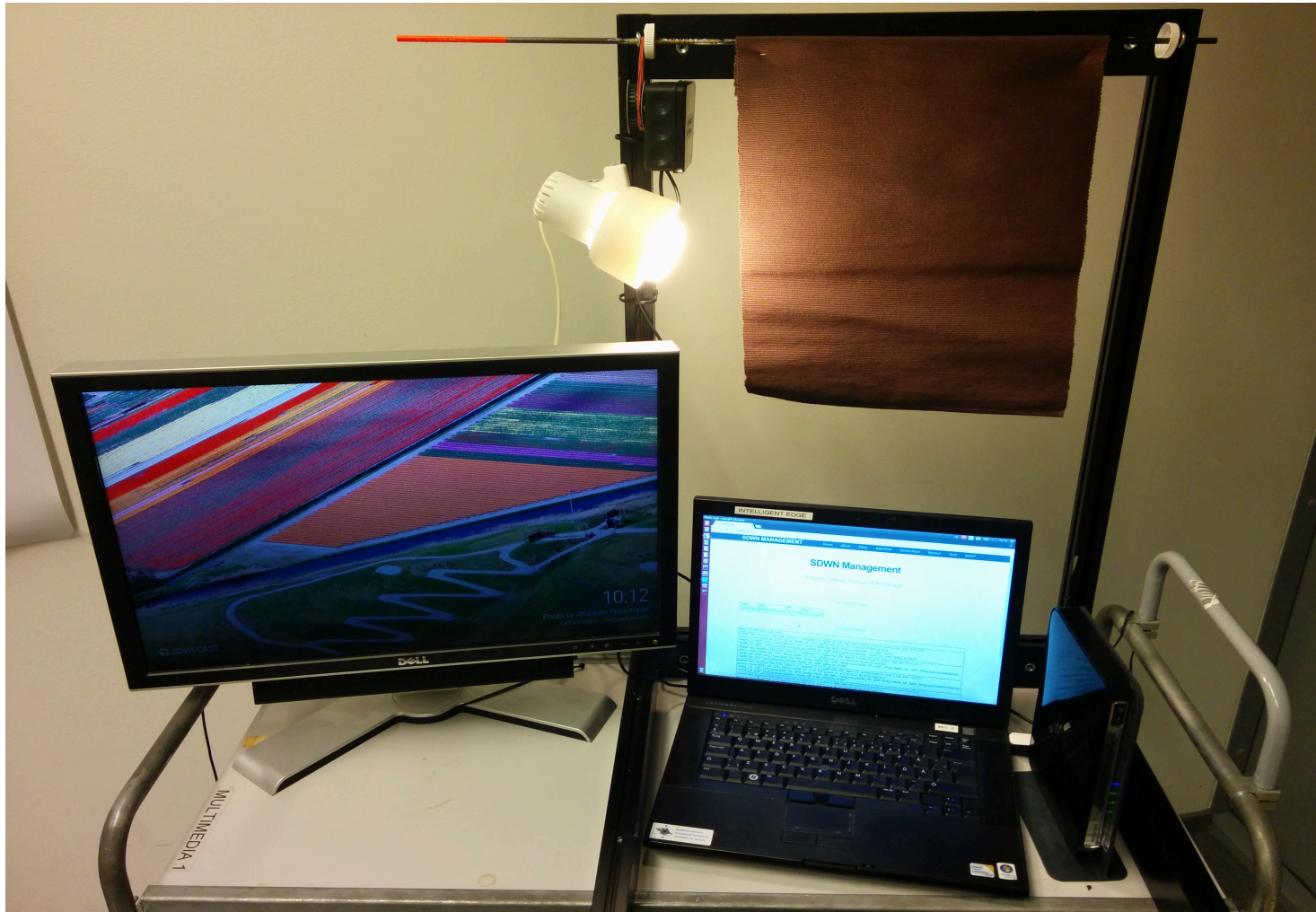
Intelligent Edge

Thin Edge

IoT Sentinel: Automated Device-Type Identification for Security Enforcement in IoT (ICDCS, 2017)



Unified Mobile Edge for IoT Devices



Programmatically manage and compose IoT devices and services

IoT hub running at the edge as an Service Function Chain (SFC) service
Intelligent AP, Philips Hue bridge and a light, Chromecast, connected curtain

Summary

Carat is a crowdsourced system that provides personalized advice and recommendations to users. The dataset is growing and the project has many directions.

Network Refactoring methodology for analysis and runtime network generation supported by network slicing

Wireless SDN for secure and stratified wireless networks

Wireless SDN and **multi-access edge computing** for **IoT** management and traffic offloading

5G Test Network Finland





Thank You!

www.cs.helsinki.fi

carat.cs.helsinki.fi

ncar.cs.helsinki.fi