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The global Internet, the last mile and the last meters

Research on the energy intensity (kWh/MB) of transmitting data

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Davos/Nagoya field study (2009): How much energy does it take to connect two conferences?

Coroama, V. C., Hilty, L. M., Birtel, M. (2012): Effects of Internet-Based Multiple-Site Conferences on Green-house Gas Emissions. Telematics and Informatics 29 2012, 362-374

Published results on kWh/MB differ by a factor of 20000 – how can we reduce the uncertainty?

Reducing the uncertainty on Internet energy intensity

Use phase energy

Core/edge networks

Seminal work by:
Baliga et al. (2007,2011)
Hinton et al. (2011,2012)
Coroama et al. (2014,2015)
Schien et al. (2012,2015)
Gray et al. (2015)

Access networks

From the last mile to the last meters

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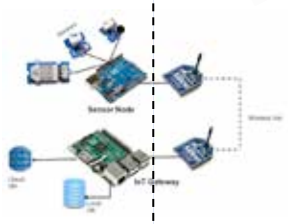
IoT



Focusing on M2M devices and traffic

Life Cycle Assessment (LCA) of "big" ICT devices

Seminal work by:
Malmodin et al. (2007…)
Moberg et al. (2010…)
Ahmadi et al. (2015)
Hischier et al. (2003…2015)

LCA of "small" ICT devices

Embedded energy becomes the major part

Roland Hischier

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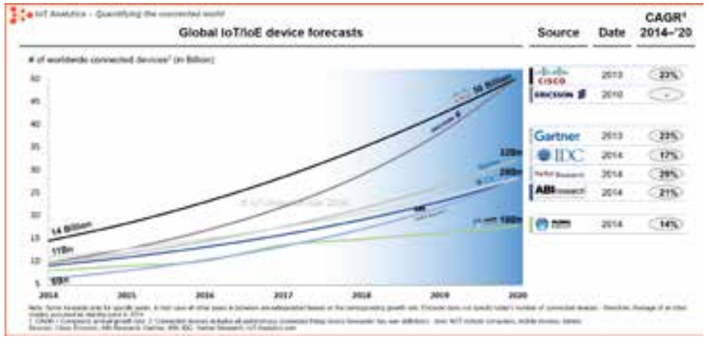
Embedded energy

Scenarios of IoT energy consumption 2014 → 2020



Device forecasts differ from 18 Billion to 50 Billion ("Internet of Everything" → we focus on M2M only)

1. How many IoT (M2M) end devices?
Cisco (2015): 3.3 Bn → 13.2 Bn

2. How much IP traffic per device?
Cisco (2015): 3.6 EB/a → 94.8 EB/a

3. Energy intensity of end device?
Own research: 0.0002-0.0015 Wh/MB

4. Energy intensity of IoT gateway (dedicated/shared)?
Own estimate: dedicated: 0.98-6.26 Wh/MB (always on); smartphone as gateway: 0.006 Wh/MB

5. How much of this traffic over which access network?
Cisco (2015): cellular: 27%-30%

6. Energy intensity of access networks
Own calculations based on lit.: home: 2.2 Wh/MB → 1.6 Wh/MB; cellular: 0.028 Wh/MB → 0.015 Wh/MB

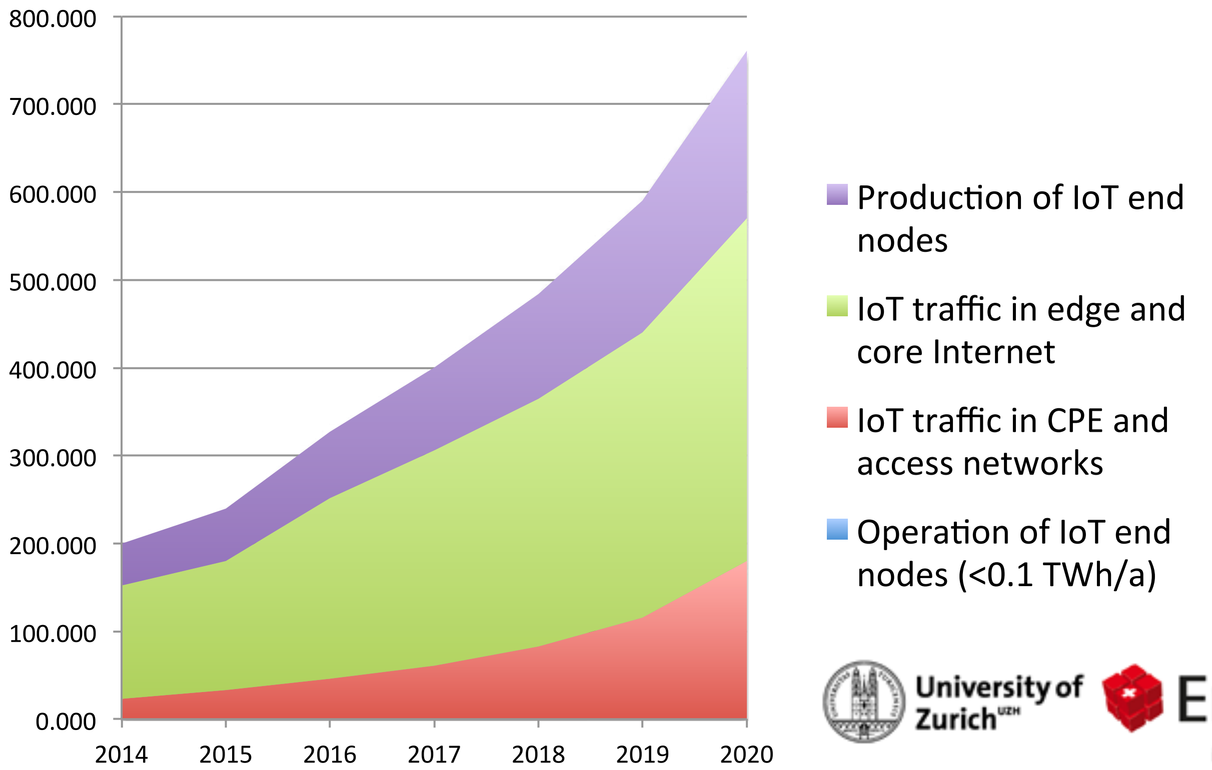
7. Energy intensity of edge/core networks
35 Wh/MB for 2014 (assuming 30% decrease per year)

8. Embedded energy per device?
Own research: 57720 Wh/device (taking NEST Protect as a model), of which 75% for electronics

Assumptions: 100% Wi-Fi; no Bluetooth, Zigbee, Z-Wave or other communications standard involved; avg. useful life: 5.0a

Projection for 2020 based on the data shown on last page

Global M2M energy consumption in TWh/a (760 TWh in 2020 ≈ 380 Mt CO_2):



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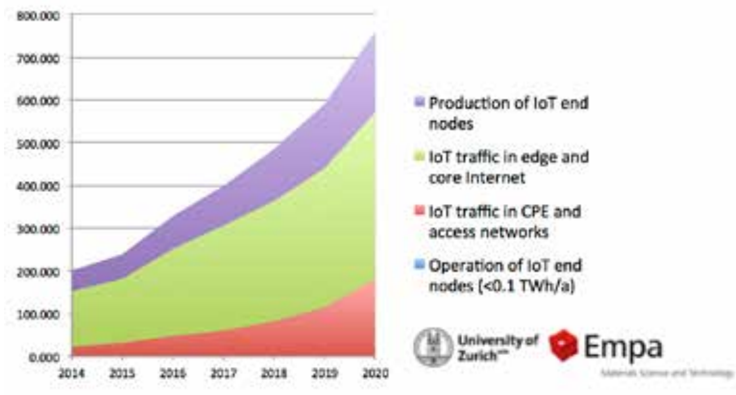
Main assumptions: 13.3 Bn M2M devices in 2020, traffic per device increasing as estimated by Cisco (2015), energy efficiency of CPE and access networks increasing by 10% per year, energy efficiency of edge/core networks increasing by 30% per year, energy needed to produce one IoT end node constant, IoT end nodes and gateways used for 5 years.

Discussion

- 380 Mt CO_2 is 27 % of predicted global CO_2 emission of the whole ICT sector in 2020 (1.4 Gt)



- The share of streaming devices in whole M2M communications is a sensitive parameter:

If we only assume that the **245 million surveillance cameras existing today** (80% still analog) are all replaced by IP cameras with HD resolution (1080p) operating only 1 h/day, this would generate

161 000 PB/a IP traffic **for cameras only**

compared to 94800 PB/a **total** M2M traffic forecasted for 2020 in our scenario.

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Is there a chance for energy self-sufficient networks?

Project idea

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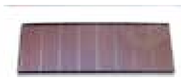
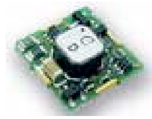
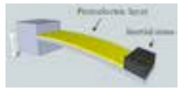
Energy efficiency progress in…

… transceivers used for IoT nodes

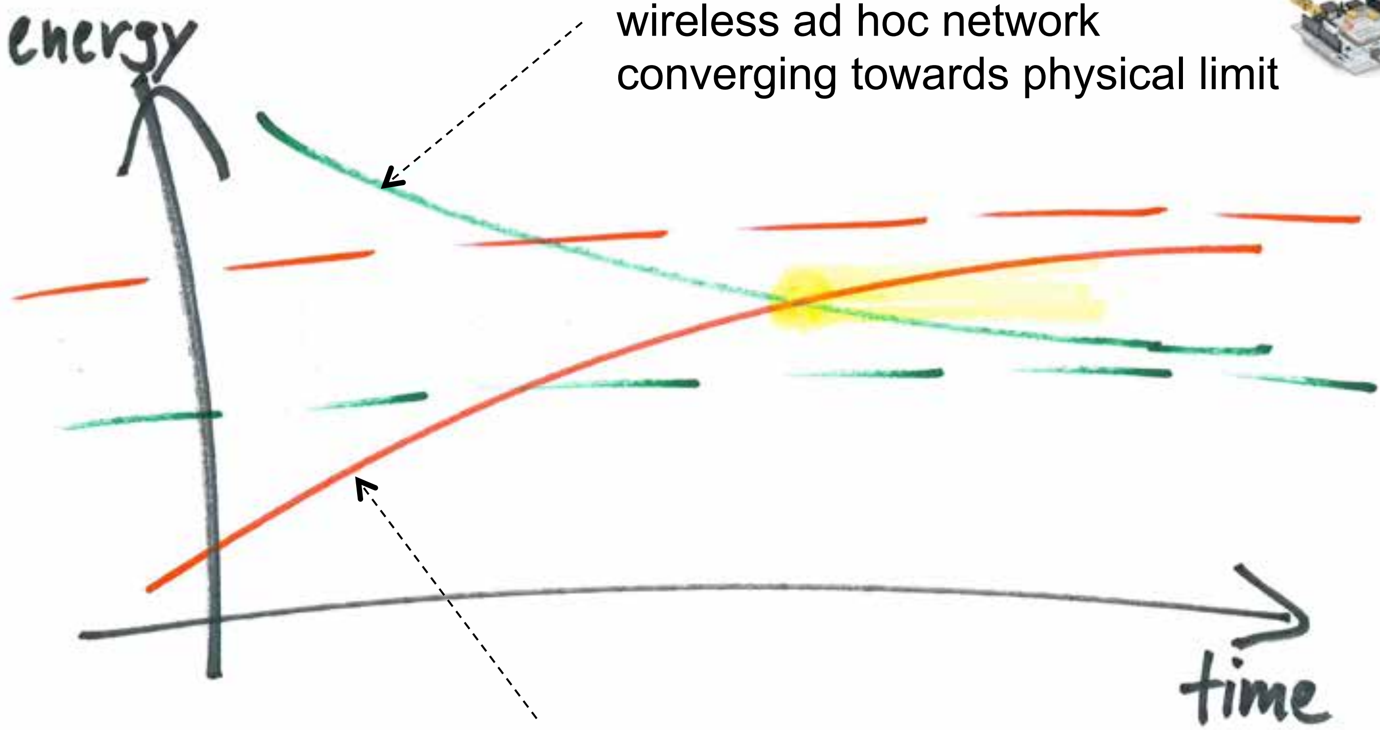
… energy harvesting technologies

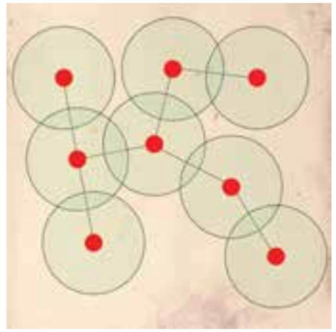
      

→ When will the combination become economically and environmentally attractive?

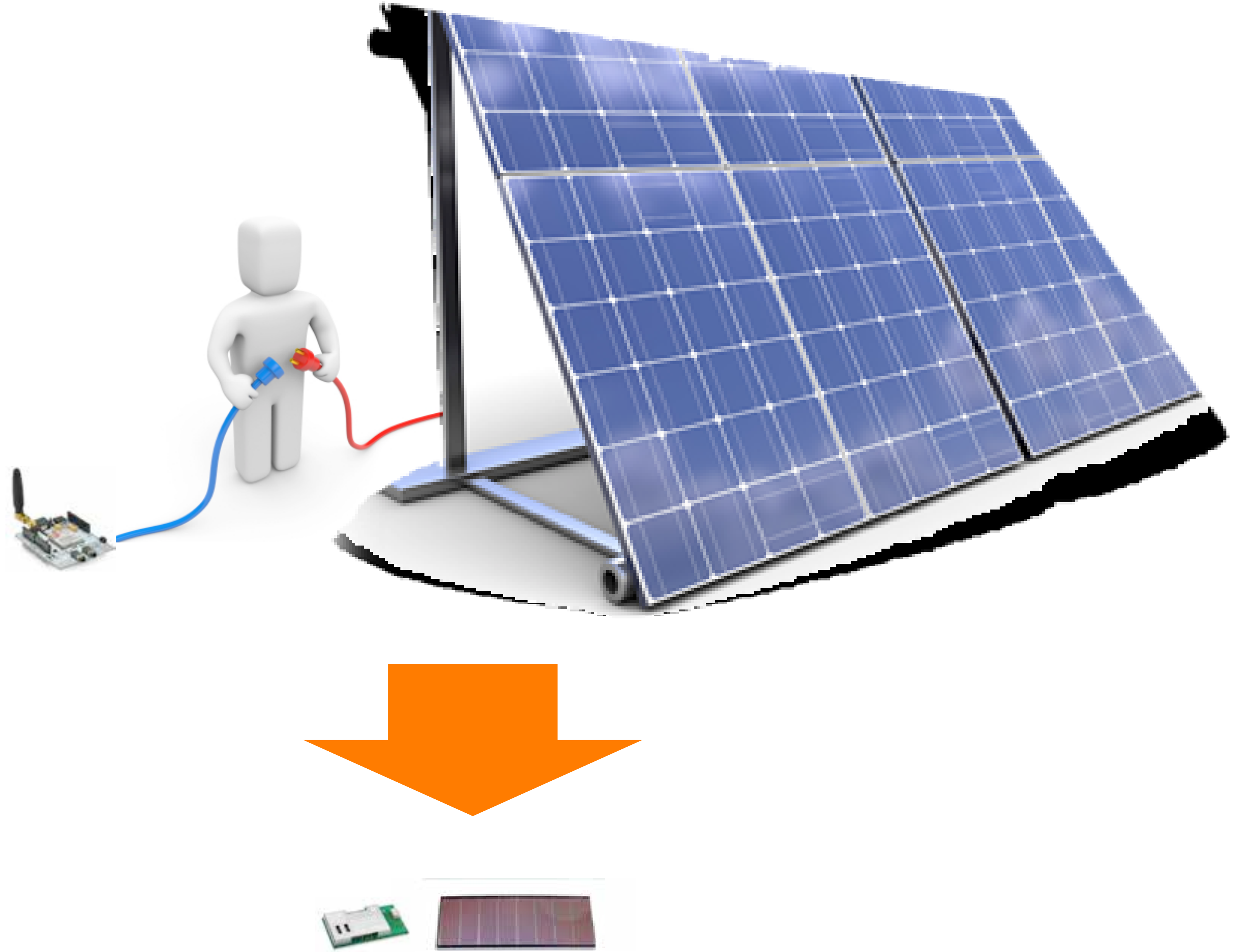
Quantify energy demand and energy supply
per unit of area

Energy demand per area to run
wireless ad hoc network
converging towards physical limit





Energy supply per area provided by
energy harvesting technology(/-ies)
converging towards physical limit(s)



Steps

1. Analyze state of the art in energy efficiency of transceiver modules (Wi-Fi, ZigBee, Bluetooth Low Energy, Z-Wave, …) and identify trend scenarios.

2. Analyze state of the art in energy efficiency of energy harvesting technologies (photovoltaic, piezoelectric, vibration, thermoelectric, radio frequency, …) and identify trend scenarios.

3. Consider expected battery, capacitor and power control trends (the glue between 1 and 2).

4. Define most promising technological development paths towards energy self-sufficient wireless ad hoc networks including
– transceiver technology
– transmission protocols
– cell size
– energy harvesting technologies for different cases (indoor, outdoor, wearable, etc.)

5. Forecast cost of all components