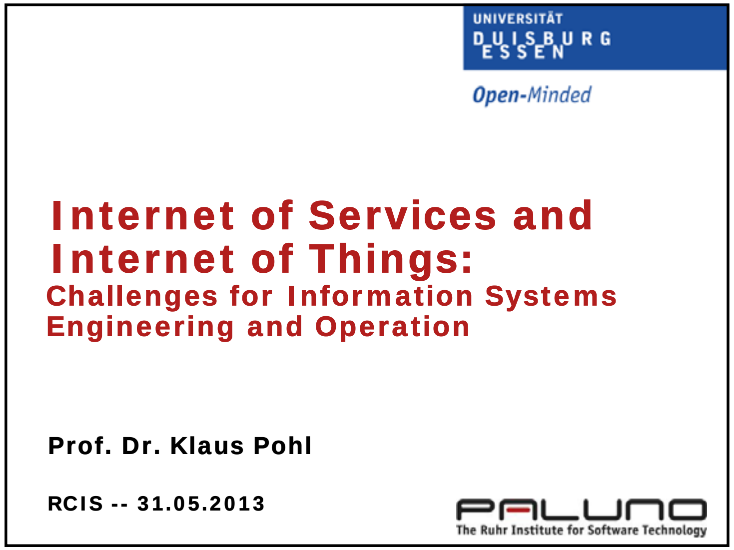
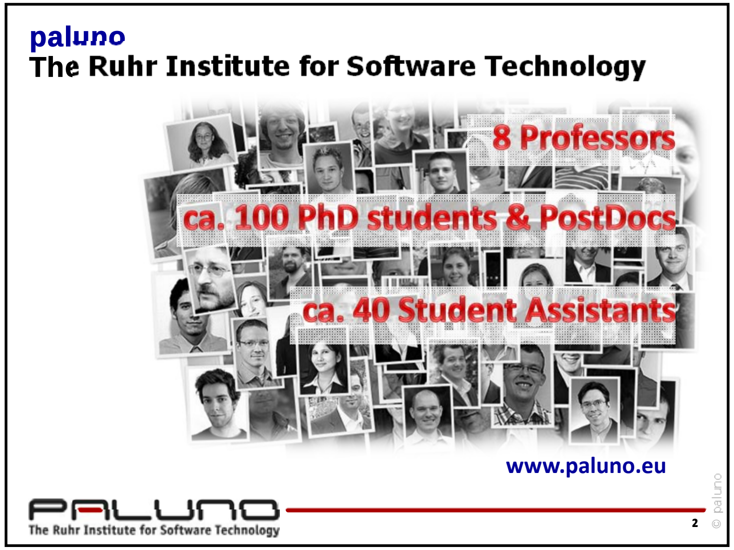
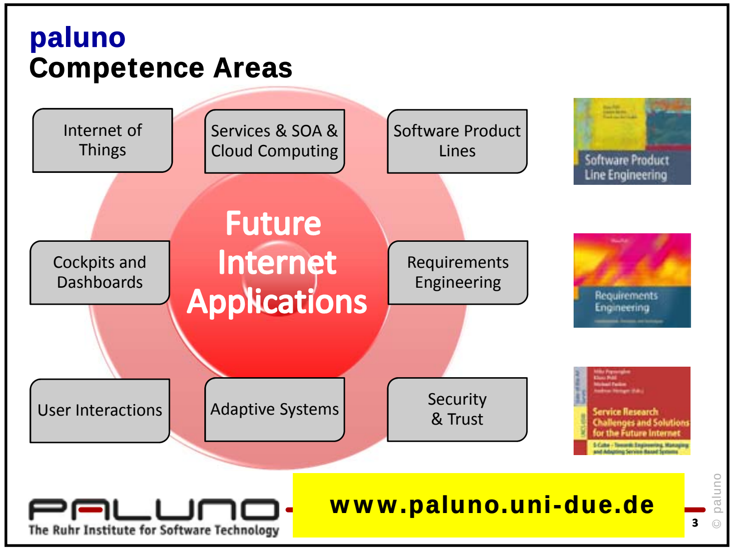
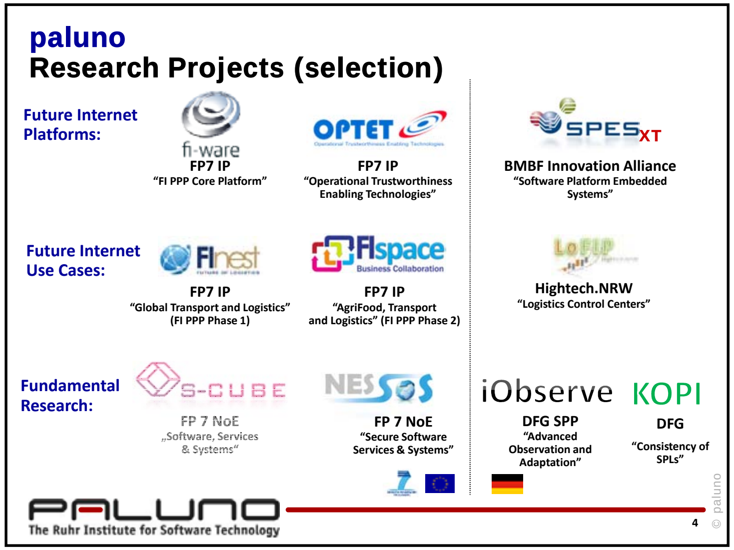

UNIVERSITÄT DUISBURG ESSEN
Open-Minded
Internet of Services and Internet of Things:
Challenges for Information Systems Engineering and Operation
Prof. Dr. Klaus Pohl
RCIS -- 31.05.2013
The Ruhr Institute for Software Technology


paluno
The Ruhr Institute for Software Technology
8 Professors
ca. 100 PhD students & PostDocs
ca. 40 Student Assistants
www.paluno.eu
The Ruhr Institute for Software Technology
2
© paluno


paluno
Competence Areas
Internet of Things
Services & SOA & Cloud Computing
Software Product Lines
Cockpits and Dashboards
Future Internet Applications
Requirements Engineering
User Interactions
Adaptive Systems
Security & Trust
Software Product Line Engineering
Requirements Engineering
Service Research Challenges and Solutions for the Future Internet
www.paluno.uni-due.de
The Ruhr Institute for Software Technology
3
© paluno

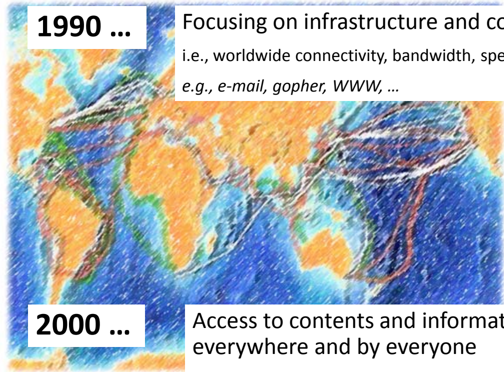

paluno
Research Projects (selection)
Future Internet Platforms:
fi-ware
FP7 IP
"FI PPP Core Platform"
OPTET
FP7 IP
"Operational Trustworthiness Enabling Technologies"
SPES XT
BMBF Innovation Alliance
"Software Platform Embedded Systems"
Future Internet Use Cases:
FInest
FP7 IP
"Global Transport and Logistics" (FI PPP Phase 1)
FIspace
FP7 IP
"AgriFood, Transport and Logistics" (FI PPP Phase 2)
LoFIP
Hightech.NRW
"Logistics Control Centers"
Fundamental Research:
S-CUBE
FP 7 NoE
„Software, Services & Systems"
NESSoS
FP 7 NoE
"Secure Software Services & Systems"
iObserve
DFG SPP
"Advanced Observation and Adaptation"
KOPI
DFG
"Consistency of SPLs"
The Ruhr Institute for Software Technology
4
© paluno

Agenda

Open-Minded

PALUNO The Ruhr Institute for Software Technology

The Internet connects the world…

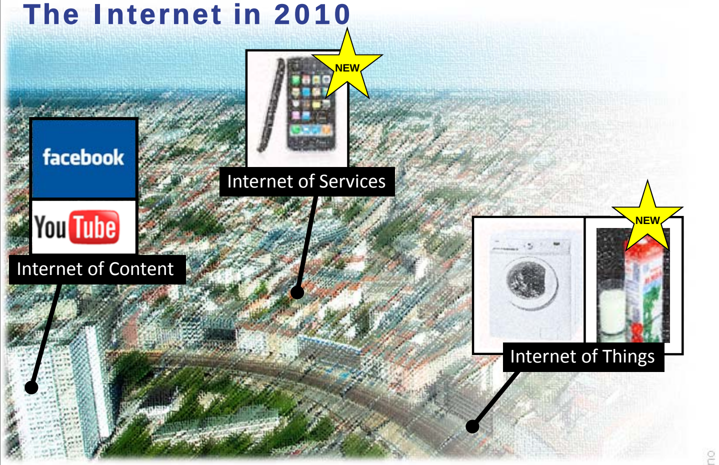


1990 … Focusing on infrastructure and communication,
i.e., worldwide connectivity, bandwidth, speed, …
e.g., e-mail, gopher, WWW, …

2000 … Access to contents and information from everywhere and by everyone
e.g., Google, Yahoo, youtube, facebook, …

PALUNO The Ruhr Institute for Software Technology

The Internet in 2010



PALUNO The Ruhr Institute for Software Technology

Internet of Services

- ***Globally accessible*** software functions (services)
- ***IT-mediated access*** to human-provided capabilities
- ***Value-add services*** through seamless composition and integration of service
- ***Cross-organizational*** data exchange and alignment of IT systems

force.com SOFTWARE

Google Docs

amazon mechanical turk beta
Artificial Artificial Intelligence

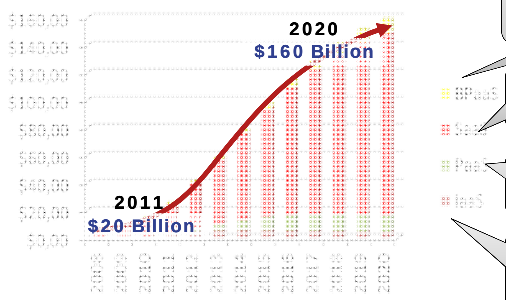
PALUNO The Ruhr Institute for Software Technology

8

PALUNO The Ruhr Institute for Software Technology

Internet of Services
Growth

Public Cloud Market Size



Business Processes / Workflows as a Service

Applications / Software as a Service

Platforms as a Service

Infrastructure as a Service: Compute, Storage, Network

PALUNO The Ruhr Institute for Software Technology

Source: S. Ried und H. Kisker, „Sizing the Cloud", Forrester Research, Inc., Apr. 2011., p. 9

Internet of Things

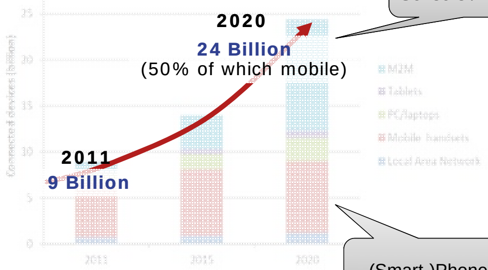
- Network **connected devices** "connecting the world to the Internet"
- **Digitization of real-world** through connected sensors and actuators
- **Uniquely identifiable objects**

PALUNO The Ruhr Institute for Software Technology

Sources: data-directions.com; xively; DHL

Internet of Things
Growth

Internet-connected Devices



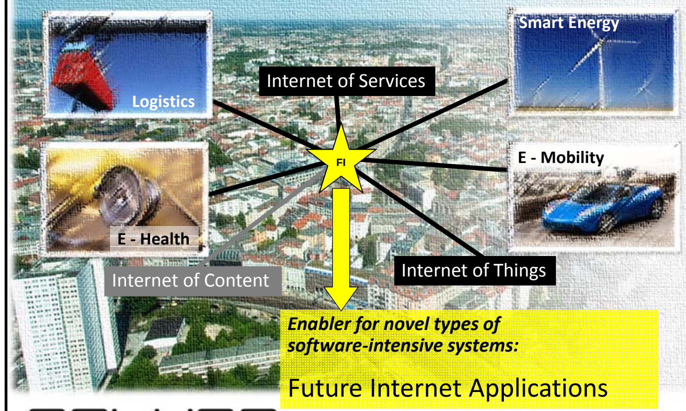
Connected Things / Sensors / Actuators

(Smart-)Phones

PALUNO The Ruhr Institute for Software Technology

Sources: GSMA und Machina Research, „The Connected Life: A USD4.5 trillion global impact in 2020", GSMA, Feb. 2012., p. 3

The Future Internet
Convergence of Services and Things



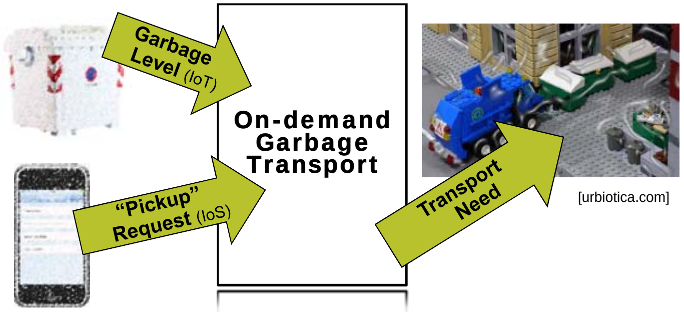
Enabler for novel types of software-intensive systems:

Future Internet Applications

PALUNO The Ruhr Institute for Software Technology

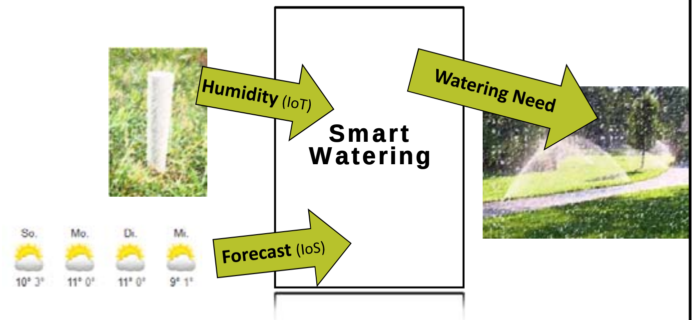
PALUNO The Ruhr Institute for Software Technology

Future Internet Applications
Example



Energy reduction: 20% (estimated)

Future Internet Applications
Example



Water reduction: 60% (estimated)

Agenda

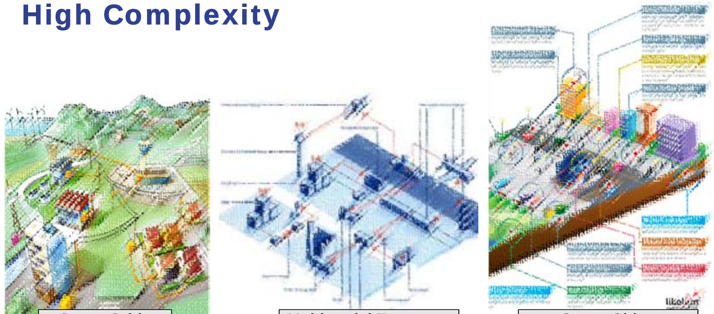
UNIVERSITÄT DUISBURG ESSEN *Open-Minded*

1. Internet of Things and Services
2. **Disruptive Trends & Challenges**
3. Monitoring & Adaptation
4. Cockpits in the Logistics Domain
5. Summary

UNIVERSITÄT DUISBURG ESSEN *Open-Minded*

High Complexity

High Complexity



Smart Grids | Multimodal Transport | Smart Cities

- **Ultra Large Scale Systems**
- **Cyber Physical Systems**
- **Socio-technical Systems**

PALUNO The Ruhr Institute for Software Technology | Sources: umd.edu; Acatech; libelium

© paluno

Think Cities not Buildings

- Dynamic communities
- Competition for resources
- Complex dependencies
- Extensive communication and interaction
- Intrinsic adaptive behavior

"Cities are pla… information flow… conduits, and m… information e…
Howard Rheingo…

PALUNO The Ruhr Institute for Software Technology | Source: L. Northrop, Keynote, ICSE 2013 | 18

© paluno

High Complexity

Ultra-Large, real-time, cyber-physical-social systems

- Are ***highly distributed*** (wireless, wired networks)
- Consist of ***thousands of sensors, actuators, platforms, services***, …
- Face ***continuous adaptations***
- ***Socio-technical*** ecosystems
- ***Cannot be pre-designed***
  - inconsistent, conflicting requirements
  - Rapid evolution
  - Stakeholders unknown

Challenge 1: How to develop and manage the evolution of systems which can **per-se not be designed a-priori**?

PALUNO The Ruhr Institute for Software Technology

© paluno

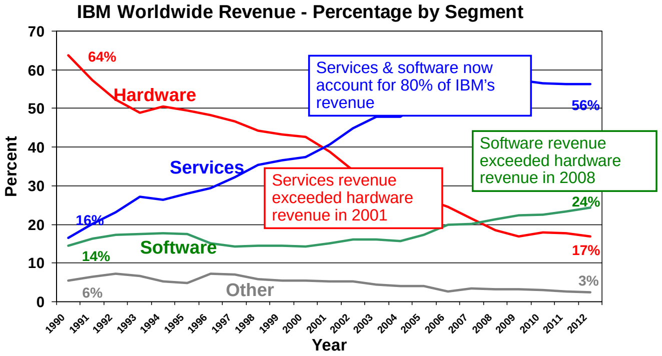
UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Servicification of Products

PALUNO The Ruhr Institute for Software Technology

IBM's Transformation
Services & Software



PALUNO The Ruhr Institute for Software Technology

Sources: Michael DiPaula-Coyle, IBM, ECIPE Workshop, 25.4.2013, IBM Financial Reports

Car and (e)-Bike Sharing

You don't buy or lease the car, but buy transportation services (time, km, …)

PALUNO The Ruhr Institute for Software Technology

Sources: car2go; nextbike

Servicification of

- ***Physical goods and products*** are
  - Enhanced and extended by services
  - Even fully turned into services, e.g., car sharing, washing-machine-as-a-service, drilling-as-a-service, …
- **Immaterial products**
  - Business processes (BPaaS)
  - Software (SaaS)
  - Platforms (PaaS)
  - Infrastructure (IaaS)
  - Content/Data (CaaS, DaaS)
  - …

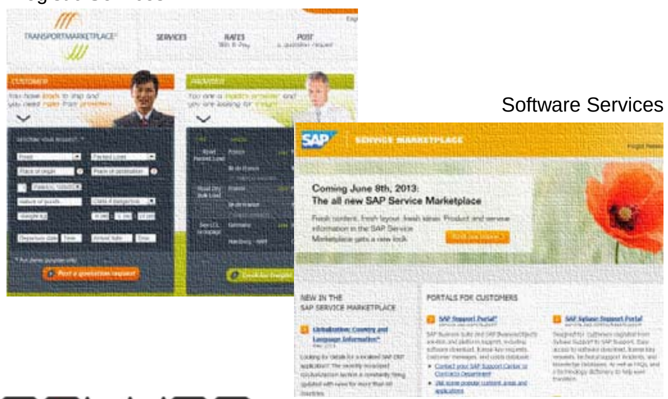
PALUNO The Ruhr Institute for Software Technology

Sources: NESSI; IFIP; Forester

Service Marketplaces

Logistic Services

Software Services



PALUNO The Ruhr Institute for Software Technology

Source: transportmarketplace.com; SAP

Impact of Servicification

- **Billions** of service-offerings
- **Trading of Services** leads to continuous change in pricing, quality, availability, …
- Extremely fast **evolution**
- Extremely fast **innovation:** New and better services appear constantly
- Systems are **composed of services** !
- Many **systems will depend on services**
  - Offered by third parties
  - Services, they don't have control over

Challenge 2: How to develop & manage the extremely fast evolution of systems based on **services you don't own and you have no control over**?

PALUNO The Ruhr Institute for Software Technology

© paluno

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Fast-paced Technology and Societal Changes

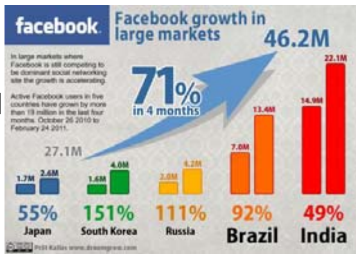
PALUNO The Ruhr Institute for Software Technology

Social Networking, e.g. Facebook

Launch of facebook: **Spring 2004**

Current # of Users

1.11 billion (March 2013)



PALUNO The Ruhr Institute for Software Technology

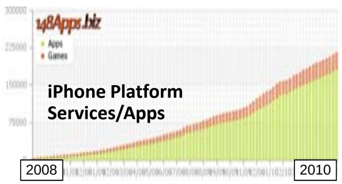
Sources: facebook, Ben Foster; dreamgrow.com

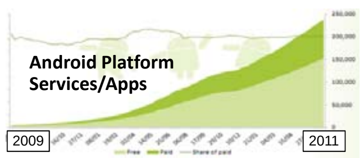
27

© paluno

Smartphone Apps

Release of 1st iPhone: June 29, 2007 (Germany 11.07)





- **Currently Active Apps** (available for download):
  - 886.127 [148Apps.biz]
- **Gartner prediction** of downloads for iPhone App
  - 2013: 80 billion
  - 2014: 130 billion
  - 2016: 300 billion

PALUNO The Ruhr Institute for Software Technology

Sources: 148Apps.biz, research2guidance

28

© paluno

Google Glass

Impact of Fast-paced Technology / Societal Changes

- ***Extremely fast***
- Radical impact on business models
  - ***Outdates*** existing business solutions;
  - ***Fast Emergence*** of new business opportunities and models
- ***Changes in user-behavior*** and ***market demands***
  - Facebook, instagram, Whatsapp, …
- Fast technology-adoption is **key for success**
  - Cf. the NOKIA story (wrt. Apps and Smartphones)
- Acceptance of solutions ***depends on anticipation of trends***

Challenge 3: How to adapt systems to ***anticipate and profit from technology and societal changes***?

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Data Flood (Tsunami)

PALUNO The Ruhr Institute for Software Technology

Digital Universe of Information
Contents, Media, Documents

2006: 160 Exabyte

1 Exabyte = 1 million TB

12 stacks of books from **earth to sun**

2010: 990 Exabyte

2013: 4.000 Exabyte

160 stacks of books from **earth to Pluto**

2020: 40.000 Exabyte

→ Basically all this information has been **produced in the last 20 years**

Impact of Data Flood

- **"Big data" analysis means handling**
  - ***Volume***: see previous slides
  - ***Velocity***: speed of data will continuously increase
    e.g., IoT sensors continuously sending data
  - ***Variety***: heterogeneity of data and data sources will proliferate
  - ***Veracity/correctness***: quality of data, uncertainty and timeliness will become important aspect to scrutinize data
- Being able to **navigate, analyze, learn** from the data flood becomes key capability for
  - Detecting ***new usage behavior*** and thus business opportunities
  - Detecting ***fault patterns***
  - ***Optimize execution***
  - …

Challenge 4: How to analyse and use "big data" obtained from sensors and services to, e.g., **optimize system execution**?

PALUNO The Ruhr Institute for Software Technology

Source: IFIP

© paluno

+ Many More (detailed Research) Challenges…

NESSI (European Technology Platform) Strategic Research Agendas on Software & Services

IFIP Cross-WG on "Services Engineering": SRII Research Challenges Paper

European **Future Internet Assembly** Roadmap

Net!Works (European Technology Platform) strategy recommendation on networking & telecommunications

EU Future and Emerging Technologies – **FET PERADA** research agenda

S-Cube Network of Excellence Research Roadmap on Service-oriented computing

EU Work Programme expert groups (service, software architectures and infrastructures; Future Internet; Cloud Computing)

Dagstuhl **seminars** and roadmaps on software engineering for self-adaptive systems

MESOA (Maintenance and Evolution of Service-Oriented Systems) roadmap driven by **SEI**

+ challenges addressed in current projects

PALUNO The Ruhr Institute for Software Technology

© paluno

Summary: Research Challenges

Challenge 1:	Develop and manage evolution of systems which cannot be pre-designed
Challenge 2:	Manage evolution of systems using services you don't own and you have no control over
Challenge 3:	Adapt systems and business to respond to (predicted) societal and technology changes
Challenge 4:	"Big data" analysis for anticipating new business opportunities and for optimizing system execution
Challenge 5:	….

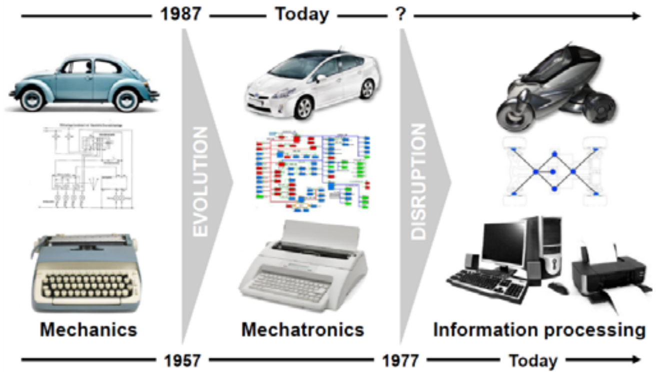
A Revolution
not "just" a Change

PALUNO The Ruhr Institute for Software Technology

35

© paluno

A Revolution?
It happened before!



PALUNO The Ruhr Institute for Software Technology

Image courtesy of Siemens

36

© paluno

PALUNO The Ruhr Institute for Software Technology

So ....

- Are existing ***engineering methods/processes*** still suited?
- Are ***traditional abstractions*** (data, function, behavior) still applicable/valuable?
- Is ***"top-down" development*** still the right approach?
- Are existing ***Quality assurance*** techniques still applicable to new types of systems?
  (testing in elastic clouds, service-replacements, ...)
- Is ***Requirements Engineering*** required or at all possible?
- ...

Most likely NOT

PALUNO The Ruhr Institute for Software Technology 37

Summary: Research Challenges

Challenge 1: Develop and manage evolution of systems which cann...

Challenge 2:

Challenge 3: ... (predicted) ...nology changes

Challenge 4: "Big da..." busines... system...

Challenge 5: ....

Clear indication that "run-time" changes and adaptation become by far more important than engineering

"Monitoring and Adaption" Is a pre-requisite for "run-time" evolution

The key challenge for systems operation!

PALUNO The Ruhr Institute for Software Technology 38 © paluno

Agenda

UNIVERSITÄT DUISBURG ESSEN *Open-Minded*

1. Internet of Things and Services
2. Disruptive Trends & Challenges
3. Monitoring & Adaptation
4. Cockpits in the Logistics Domain
5. Summary

PALUNO The Ruhr Institute for Software Technology

Monitoring & Adaptation

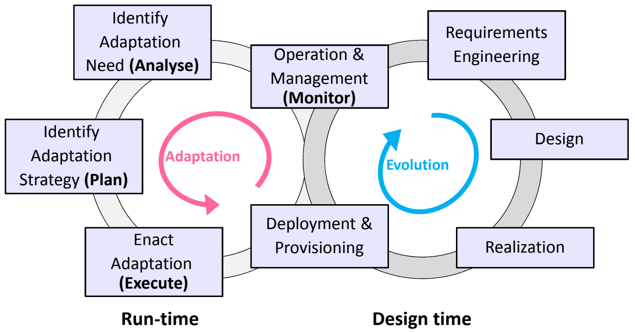
= Ability of systems to ***observe*** execution, context etc. + **analyze** observation (identify need to adjust) + **plan and execute** adaptation

Facilitates

- Run-time evolution (Challenge 1);
- Limited control over services (Challenge 2);
- Adaptation to business process and technology changes (Challenge 3);
- Exploitation of big data analysis results for system optimization (Challenge 4)

PALUNO The Ruhr Institute for Software Technology 40 © paluno

Monitoring & Adaptation
S-Cube System Life-Cycle Model



"MAPE" loop [Salehie & Tahvildari, 2009]

Monitoring & Adaptation

- Automation requires **formalization** (codification) **of knowledge** required for MAPE
- Required knowledge **can only partial be defined** and formalized at engineering time
  - Partly not known a priori
  - Too much effort to define and formalize
  - Conflicting and inconsistent information
  - Dynamic changes over time
  - ...
- ***Full automation close to impossible***

➔ Monitoring and Adaptation typically requires Human-in-the-Loop

"Traditional" Cockpits & Control Centers

- ***Common solution for monitoring and adapting operational process*** in several application areas, e.g.,
  - Emergency
  - Disaster management
  - Chemical plants
  - Production automation
- ***Human-in-the-Loop***
  - Monitoring
  - Analysis
  - Decision-making
  - Adaptation (execution of)

Sources: npc.org, parabolicarc

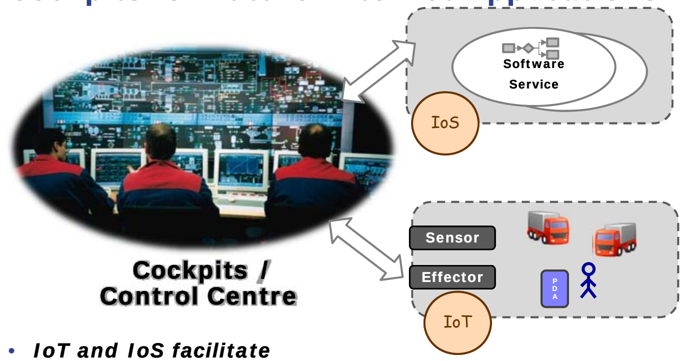
Agenda

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

1. Internet of Things and Services
2. Disruptive Trends & Challenges
3. Monitoring & Adaptation
4. Cockpits in the Logistics Domain
5. Summary

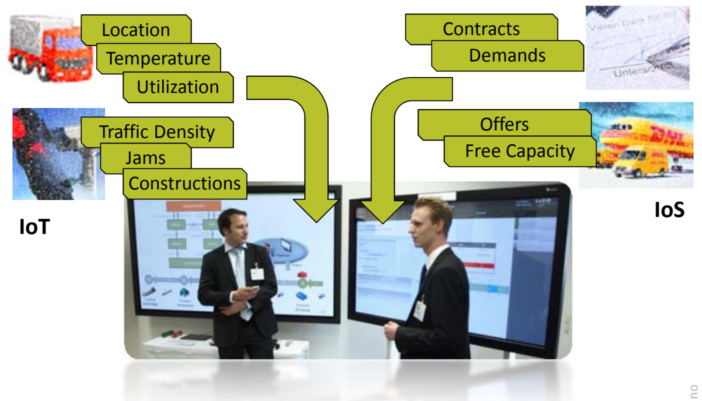
PALUNO The Ruhr Institute for Software Technology

Cockpits for Future Internet Applications

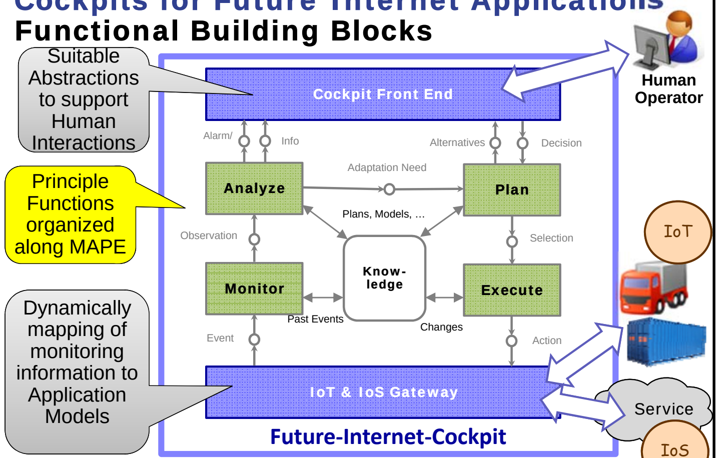


- ***IoT and IoS facilitate***
  - Cockpits for many ***operational processes in various domains***
  - Collection ***real-time information about operation, context, users*** etc.

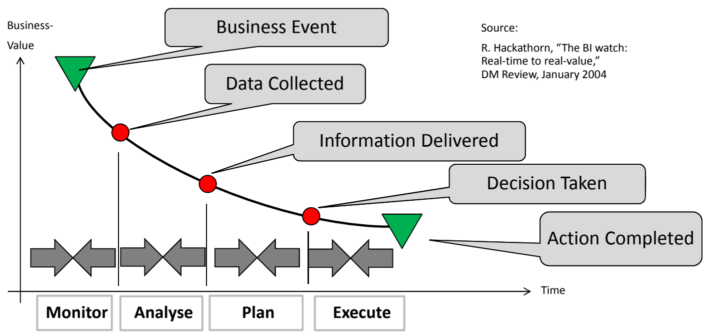
Cockpits for Future Internet Applications
Example: Transport & Logistics



Cockpits for Future Internet Applications
Functional Building Blocks

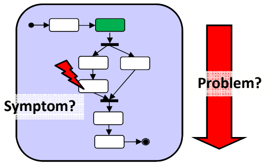


Cockpits for Future Internet Applications
Better Responsiveness through MAPE



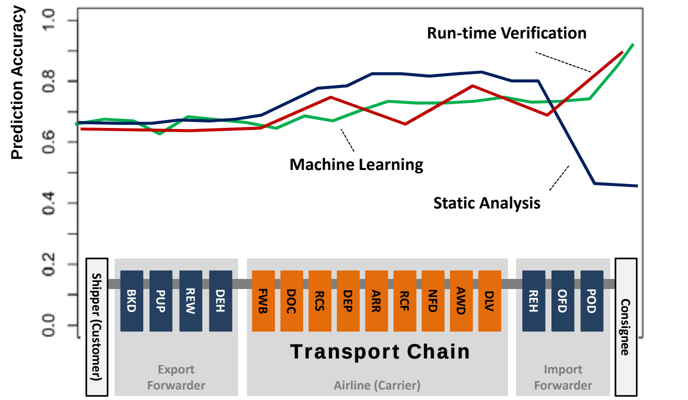
Cockpits for Future Internet Applications
Even Higher Responsiveness through Prediction

1) ***Real-time prediction*** of symptoms such as prediction of ***delays***, anticipation of ***volume discrepancies***, ***quality failures***, …



2) ***Proactive Adaptation*** to mitigate and avoid problems resulting from symptoms, e.g., replanning of transports, rerouting of passengers, …

Cockpits for Future Internet Applications
Prediction Results



Operational data: 4000 transportation processes; over 5 month

Agenda

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

1. Internet of Things and Services
2. Disruptive Trends & Challenges
3. Monitoring & Adaptation
4. Cockpits in the Logistics Domain
5. Summary

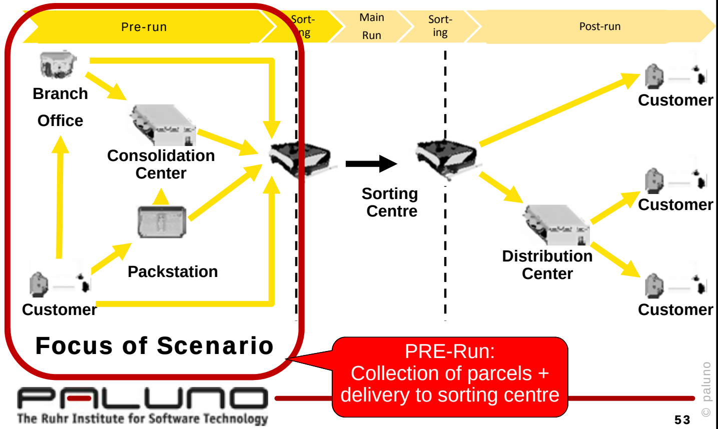
The LoFIP Project

- Aim: **Federated Future-Internet-Cockpits for robust and resource-efficient execution of transport processes**
- Duration: **07/11 – 07/14** **Budget:** 6.5 Mio EUR
- Partners:

Universität Duisburg Essen, duisport, RWTH Aachen University, SDZ GmbH, SAP, Deutsche Post DHL (associated)

Software & IT (~ 66%)	Logistics (~ 33%)	Industry (~ 40%) / Academia (~ 60%)

Application Scenario 1
Parcel Logistics



Application Scenario 1
Parcel Logistics

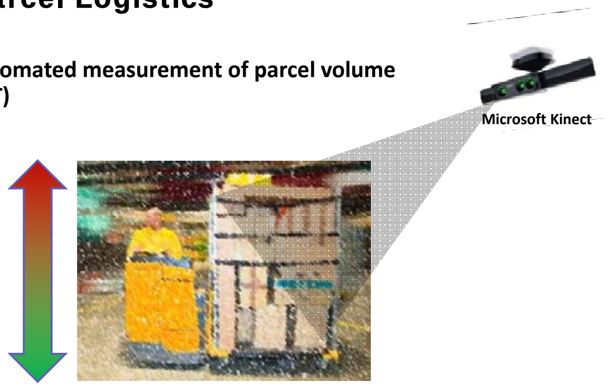
- **High variation of parcel volume**
  - High variation in prediction of actual volume based on statistic and experience

→ Insufficient truck capacity
  - Not all parcels can be collected
  - Violation of service promises
  - Customer dissatisfaction

→ Overload in sorting centre
  - Unbalanced number of parcels/hour
  - Causes delays (unsorted parcels)
  - Leads to significant higher personnel costs

Application Scenario 1
Parcel Logistics

Automated measurement of parcel volume (IoT)

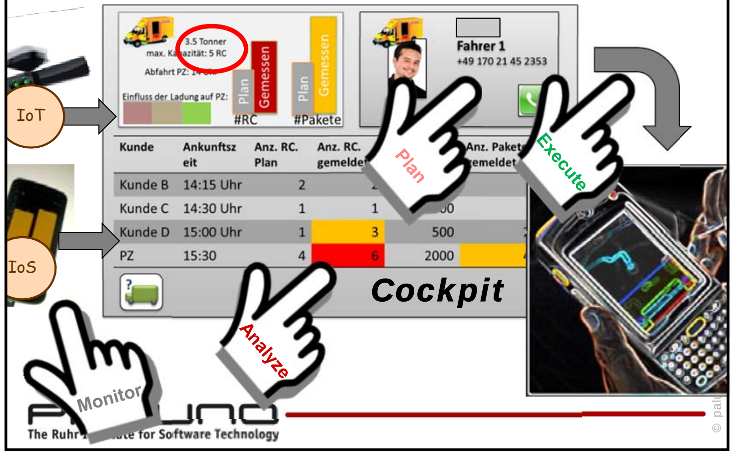


Application Scenario 1
Parcel Logistics

Automated measurement of parcel volume (IoT; IoS)

Smartphone-based online collection of transport volume

Application Scenario 1
Parcel Logistics -- Operation Cockpit



Application Scenario 2
Container Logistics

http://www.youtube.com/watch?v=hySGKbEEsyo

The LoFIP Approach

1. **Scenario-driven** development and validation
2. Highly incremental development using **Mockups and evolutionary prototypes**
3. **Continuous validation** with domain partners
4. **Realistic use of prototyp**[es in] our Living Lab

→ **Identification of research challenges based on experience**

Cockpits for Operational Processes

Some challenges:

- ***Development of usage scenarios***
  requires domain and IoT, IoS knowledge; often disruptive
- ***Adequate consideration of context***;
  Enriched application models; context models; dynamic adaptation of models; Required, e.g., to facilitate the mapping of monitoring information to application
- ***Monitoring system execution***;
  Not straightforward in a cloud environment (limited observability)
- ***Dynamic replacement*** of sensors and actuators
- ***Aggregating of monitoring information***;
  Right level of granularity / abstraction levels; domain specific; situation specific
- ***Human interaction metaphors and „protocols“***
  What can we learn from „traditional“ cockpits; what needs to change?
- **...**

Agenda

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

1. Internet of Things and Services
2. Disruptive Trends & Challenges
3. Monitoring & Adaptation
4. Cockpits in the Logistics Domain
5. Summary

PALUNO The Ruhr Institute for Software Technology

Summary: "Changes"

High Complexity (Ultra large scale and cyperphysical systems)

Develop and manage evolution of systems which ***cannot be pre-designed***

Servicification of Products (cars, washing machines, tires, …)

Manage evolution of systems using ***services you don't own and you have no control over***

Fast-paced Technology and Societal Changes (iPhone, Apps, Facebook, Instagram, …)

Adapt systems to ***respond to (predicted) societal and technology changes***

Data Flood (Tsunami) (data from process execution, IoS, IoT, …)

Anticipating new business opportunities and ***optimizing system execution*** based on big data analysis

+++

PALUNO The Ruhr Institute for Software Technology 62 © paluno

Summary – Radical Change / Revolution?

For many future systems (not all)

- **Today's system development methods (incl. agile) will not work**
- **Today's abstractions (data, function, behaviour) are by far not sufficient**
- **There is no grand design !**
- **Quality Assurance methods do not work at @ run-time (if for ULS, CPS at all)**
- **…**

→ **Disruptive research results & solutions (not adapting known solutions to new problems ☺)**

→ **Rethinking about funding policies, publication strategies, review processes, +++**

PALUNO The Ruhr Institute for Software Technology 63 © paluno

Further Information:

www.paluno.eu

www.sse.uni-due.de

www.lofip.de
www.fispace.eu
www.s-cube-network.eu

PALUNO The Ruhr Institute for Software Technology © paluno