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The benefits of embedded intelligence - Tasks and applications for ubiquitous computing in logistics

Institute for Microsensors, -Actors and –Systems
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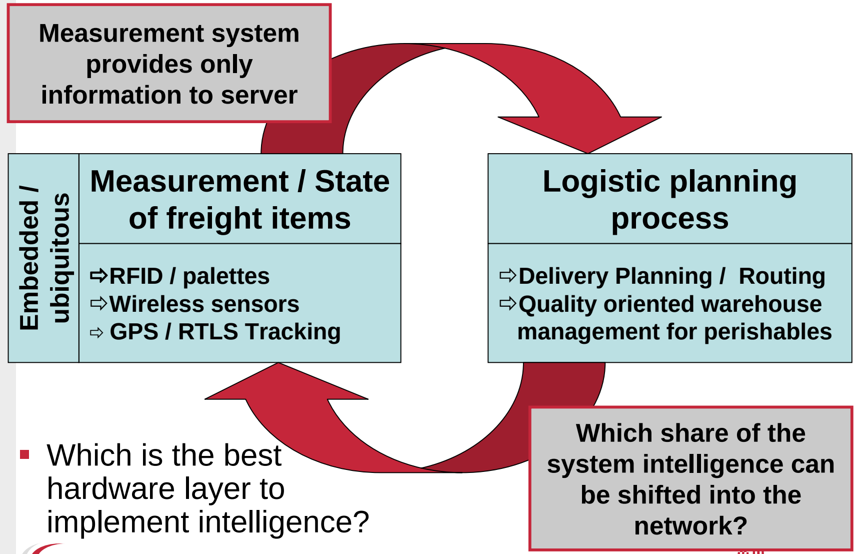
Introduction



- Which is the best hardware layer to implement intelligence?

Outline

- Background of embedded intelligence
  - Autonomous cooperation
  - Hardware layers
  - Communication as limiting factor
- Case studies and examples
  - The intelligent container
  - Local route planning
  - Intelligent RFID + Business case

1

Autonomous control means that intelligent objects make decisions on their own. Parcels, vehicles or transport orders are represented by individual software programs or agents.

Intelligent objects

- Each object is equipped with a certain **Degree of decision freedom**

None

- Executes decisions of central server
- Observes its environment
- Change transport route
- Swap vehicle by own decision
- Changes its destination, according to new orders or changed quality state

Maximum freedom

Object representation

- Agent **physically** linked to object
  - Object / parcel has own computation unit
- Agent **represents** object
  - Agents runs remote on server platform to act ‘in behalf’ of the object

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Various system layers can provide a platform for embedded intelligence. The costs for additional computation power are low in relation to the basic hardware costs

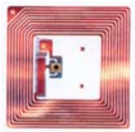
Hardware Layers

PC / Server

Truck / Container

Sensor network

RFID



Limiting factors of communication

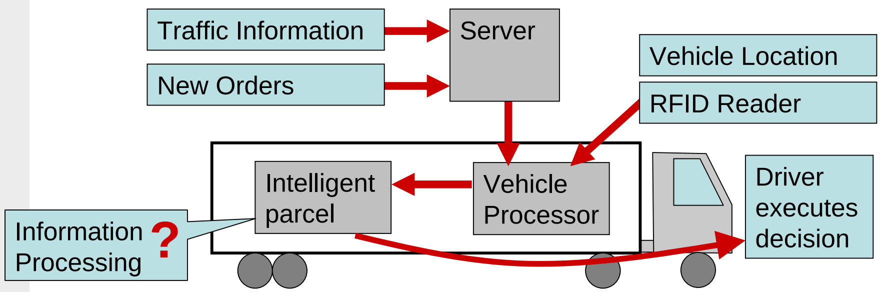
- Passive RFID:
  - Access only **offline** during gate passage
  - Limited range (~3 m)
- Active wireless sensor:
  - Permanent **online** access and higher range
  - But volume limited by energy budget
- Thinking is cheaper than communication
  - Sending one message ⬄ 3 Seconds CPU at full speed
  - Local data possessing extends battery life time by reduces communication

3

Information should be sent over the shortest path from source to sink. Implementing the decision system on the 'wrong' hardware layer could even increase the communication volume.

The example of the intelligent parcel

- Length of the information path
  - Source → Processing → Sink



Length of the information path

- Keep it as short as possible
  - Length depends on location of the processing
- Processing close to origin of information
  - Route decision ~ 100 Byte
  - Sensor supervision ~ 10 kByte

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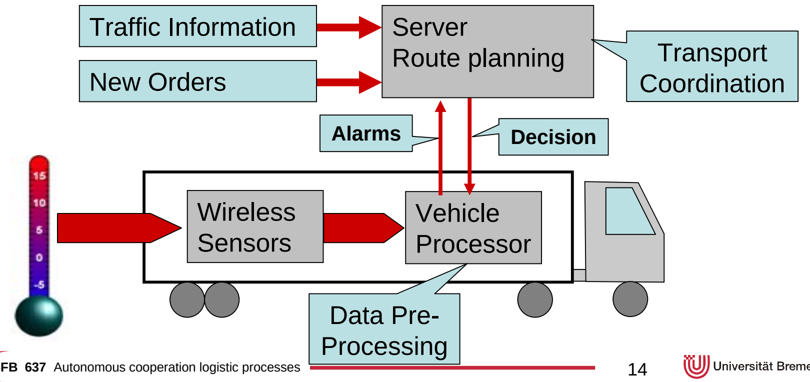
The supervision of perishable goods creates a different communication setting: The high data volume by freight temperature measurements requires local pre-processing.

Intelligent Container

- Supervision of perishable goods



Transfer of the intelligent container

- CCG Holding AG
  - CCG FRA
  - Rungis Express
- Dole Fresh Fruit Europe OHG
- Cargobull Telematics GmbH

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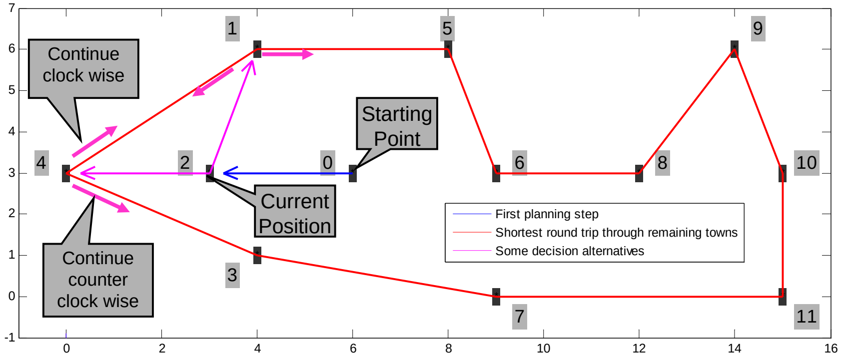
Splitting the planning system into embedded units could largely reduce communication. But embedded systems cannot decide from a ‘birds-view’ perspective.

Splitting the route planning process

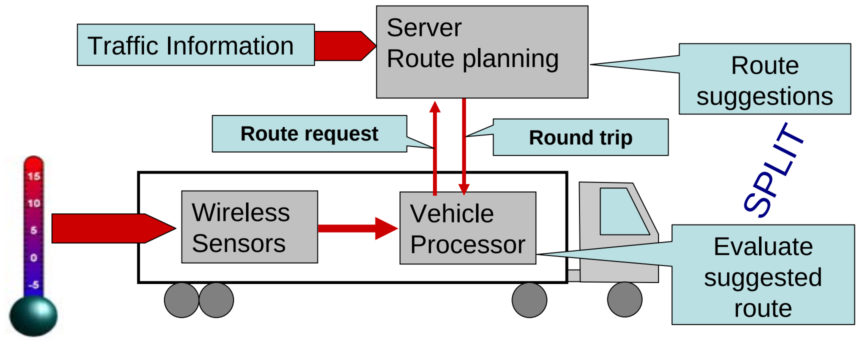
- **Example:** Truck autonomously adapts a round trip to deliver sensitive parcels to multiple costumers
- **Split Planning:** Remote server suggests round trip, truck decides to go clockwise or count clockwise and where to start



- Unit: Travel distance in hours

Local Route Planning

- Reduced information: Vehicle receives only a limited number of route suggestions
- Truck evaluates the suggestions by internal quality information
  - Deliver packages with low remaining shelf life first
  - Maximize the number of deliveries in proper quality state



Performance of different planning strategies

- How good is planning under this restriction?
- Vehicles start with optimal route, but disturbance and re-planning after 2 packages
- 500 software experiments with N_0 = 20 packages to deliver

Method	**Delivered Packages**	**Driving time**	**Improvement**
Full re-planning **(Bird view)**	16.41	76.81 hours	100 %
Vehicle planning **(Local view)**	15.66	76.82 hours	64.5 %
Repeated vehicle planning	15.75	75.80 hours	68.6 %
Unchanged route	14.30	74.68 hours	0 %

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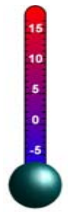
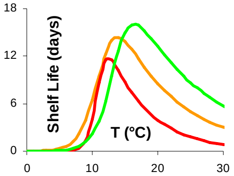
Automated evaluation of temperature charts is even feasible inside the hardware of semi-passive RFID labels.

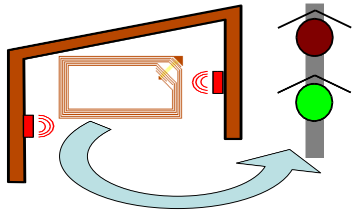
The idea of intelligent RFID

- Sensor data pre-processing by semi-passive RFID tags

Temperature measurement	Function to access effects of temperature onto quality	Only state flag transmitted at read out

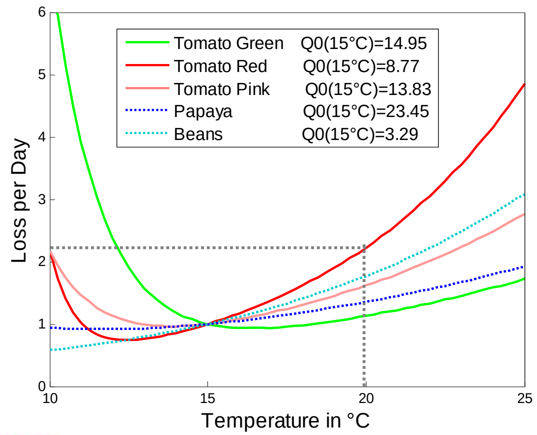






Shelf life modeling

- Calculation of loss per day as function of temperature
  - Arrhenius equation for reaction kinetics
  - Look up table



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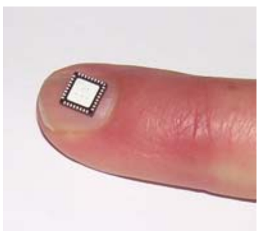
Horticultural Production Chains (HPC)

Required hardware resources

- Is it feasible to squeeze a shelf life model into a micro-chip?

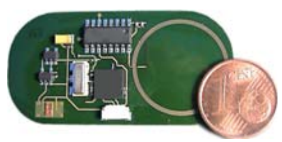
Type of Resource	Calculation of Arrhenius equations
Processing time	1.02 ms
Program memory	868 bytes
RAM memory	58 bytes
Energy	6 µJoule



Available energy

- Very small additional recourses compared to circuit of data logger
- Shelf life model can run by paper thin batteries
- Finished project: HF-Tag for Measurement of pressure

Power consumption per month	
Update every 15 minutes	0.020 J / month
Stand by current of MSP430 (1µA at 2.2V)	5.7 J / month
Turbo Tag (Zink oxide battery)	80 J



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If warehouse management is organized by actual shelf life instead of fixed expiration dates, the average quality could be increased and losses reduced.

Application to warehouse management

- First expires first out (FEFO)
  - Send palettes with low shelf life immediately to nearby stores
  - Keep palettes with high shelf life for long distance transports / long term storage
  - → Reduction of waste
- Case study on strawberries by the University of Florida
  - Center for Food Distribution and Retailing (J.P. Emond)
- Truck with 24 palettes of strawberries
  - Temperature sensors in each palette
  - Manual quality assessment
  - Comparison with shelf life prediction

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Strawberries – Case Study

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Waste at the store level (22 pallets sent)

Days left	Number of pallets	Waste random retail	Waste (FEFO planning)	(Recommendation)
0	2	91.7%	(rejected)	(don't transport)
1	5	53 %	(25%)	(sell immediately)
2	8	36.7%	(13.3%)	(nearby stores)
3	7	10%	(10%)	(remote stores)

Revenue and profit

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	Actual	FEFO Approach
REVENUE	$47,573	$58,556
COST	$49,876	$45,480
PROFIT	($2,303)	$13,076

Summary

- Benefits of embedded intelligence
  - Large reduction of communication costs
  - Only few extra hardware costs for additional processing power
  - Increased robustness and flexibility

  - Not all hardware levels are useful
  - Length of the communication path

Thank you for your attention

For more information and publications please visit

www.intelligentcontainer.com

- Contact address

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