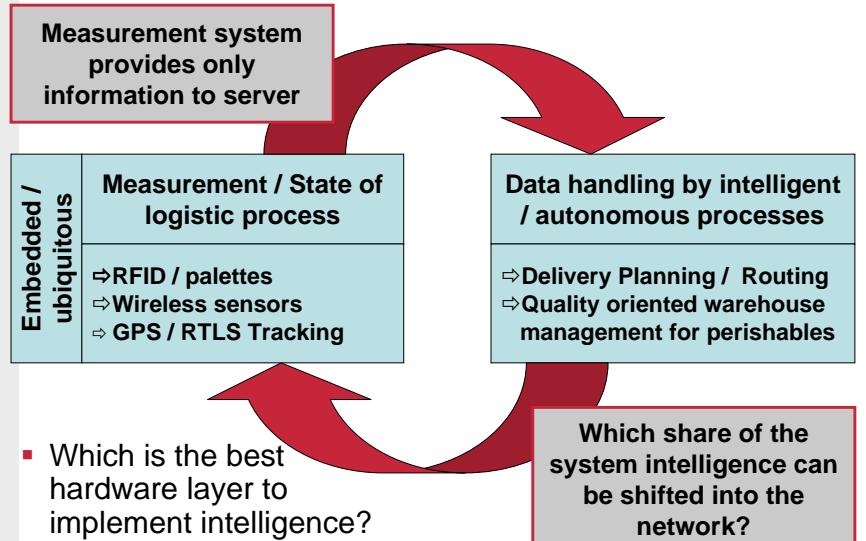


R. Jedermann and W. Lang

Intelligent parcel or intelligent vehicle? System layers to implement embedded intelligence

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

Autonomous control

- Decentralized decision making
- Split (logistical) planning tasks into parallel processes
- Ideal case: each object represented by its own software entity / Software agent
- Object = parcel, vehicle or a single order
- Advantages: Robustness, Flexibility for system dynamics
- 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

Degree of decision freedom

Decision scope	Description
None	<ul style="list-style-type: none"> Executes decisions of central planning instance
Evaluation of local sensor information	<ul style="list-style-type: none"> Observes its environment Decides whether measured deviations form a risk for the good quality
Adaptive route planning	<ul style="list-style-type: none"> Change transport route swap vehicle by own decision
Maximum decision freedom	<ul style="list-style-type: none"> Changes its destination, according to new orders or changed quality state

Implementation levels

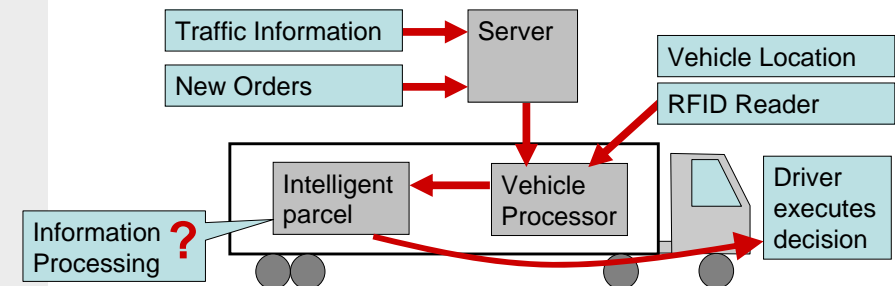
Location	Current application	Future applications	Computation power	Basic costs	Extra costs
Server networks	Objects representation by Global database	Multi agent system based vehicle routing	100%	> 1000 €	-
Means of transport	Telemetric supervision, GPS	Intelligent Container	~2 %	< 1000 €	~ 100 €
Active communication devices	Active tags attached to containers	Spatial supervision by wireless sensors networks	~0.1 %	> 10 €	~ 1 €
(semi-) passive RFID tags	Identification Temperature logging	Intelligent RFID	<< 0.1 %	> 1 €	~ 1 €

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

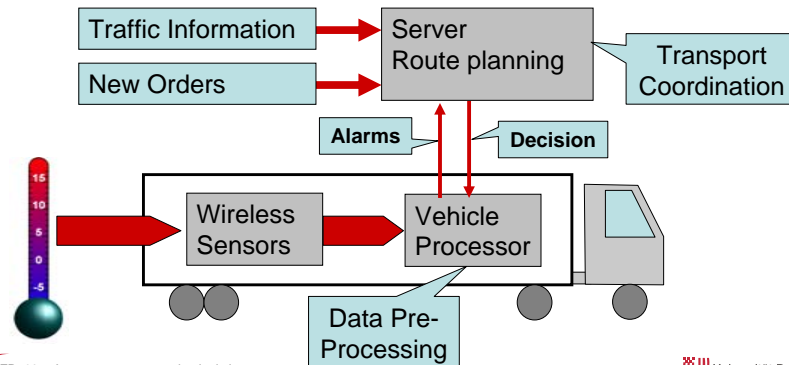
Where to place the data processing?

- How is information transferred?
 - Source → Processing → Sink
- Length of the information path



Intelligent Container

- Supervision of perishable goods

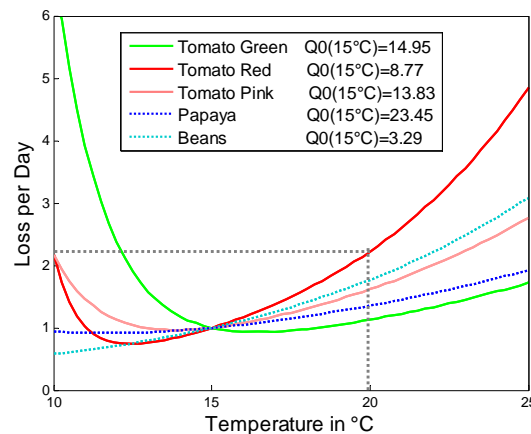


Length of the information path

- Keep it as short as possible
 - Does the shift of intelligence to another system layer shortens or extends the communication path?
- Processing close to origin of information
 - Sensor supervision ~ 10 kByte
 - Route decision ~ 100 Byte
- Thinking is cheaper than communication
 - (1 mJ < 16.5 mJ for wireless sensors)
 - If intelligence reduces communication it enables networked objects

Shelf life modelling

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



Local Route planning

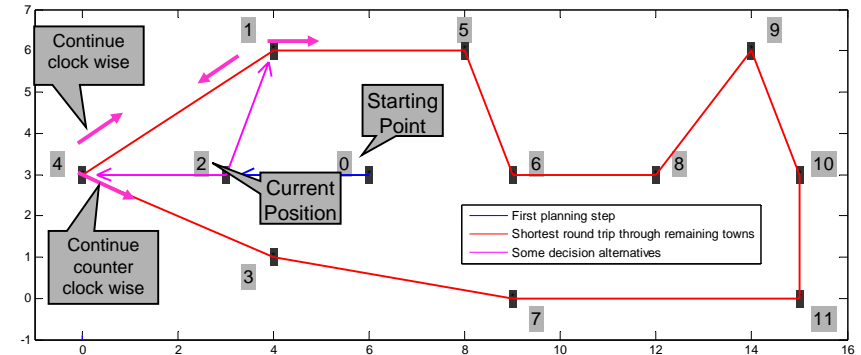
- Alternative to the intelligent parcel
- Example: Truck autonomously adapts a round trip to deliver sensitive parcels to multiple costumers
- Truck does not check all possible round trips (Travelling salesman) only local view
 - Embedded objects have only limited access to information, no bird view**
 - How good is planning under this restriction?

Approach for intelligent truck

- Privacy: Vehicle does not send quality data to the outside world
- Reduced information: Vehicle receives only a limited number of route suggestions
 - Provided by external traffic information server
- Truck evaluates the suggestions on the bases of the internal quality information
 - Change the route to deliver packages with low remaining shelf life first
 - Maximize the number of packages in proper quality state at point of time of delivery

Experimental evaluation

- Distributed heuristic solution
 - Software simulation
 - Comparison with optimal solution
- Process repeated in each town
 - Unit: Travel distance in hours



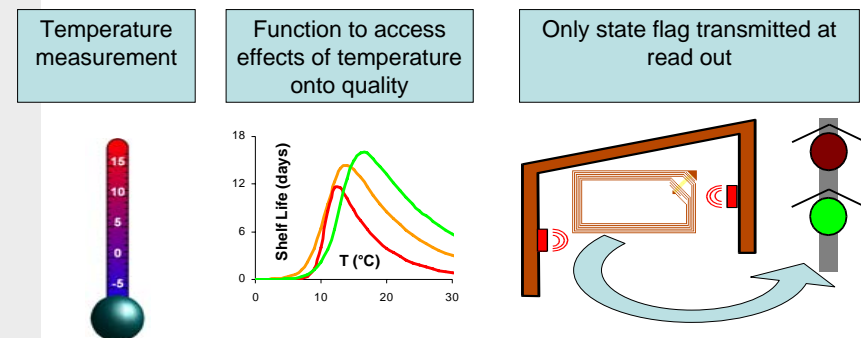
Performance of different planning strategies

- Vehicles start with optimal route, but disturbance and re-planning after 2 packages
- $N_0 = 20$ packages to deliver
- 500 software experiments

Method	Delivered Packages	Driving time	Improvement
Full re-planning	16.41	76.81 hours	100 %
Local vehicle planning	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 %

The idea of intelligent RFID

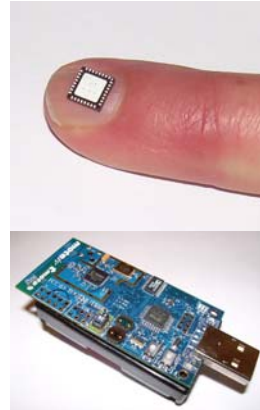
- Sensor data pre-processing by semi-passive RFID tags



Required hardware resources

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

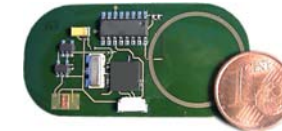
Type of Resource	Calculation of Arrhenius equations
Processing time	1.02 ms
Program memory	868 bytes
RAM memory	58 bytes
Energy	6 μ Joule



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 (1 μ A at 2.2V)	5.7 J / month
Turbo Tag (Zink oxide battery)	80 J



Summary

- Benefits
 - Robustness
 - Flexibility
 - Privacy
 - Less communication costs
 - Only few extra hardware costs for additional processing power
- 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

- Full paper will be presented at the Internet of Things March 2008, Zurich:
 - The Benefits of Embedded Intelligence - Tasks and Applications for Ubiquitous Computing in Logistics. In: C. Floerkemeier et al. (Eds.): IOT 2008, LNCS 4952, Springer Berlin Heidelberg 2008, pp. 105–122,
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