Technische Universität Braunschweig

Institut für Betriebssysteme und Rechnerverbund

Ballistic Deployment of WSN Nodes using Model Rockets

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Institute of Operating Systems and Computer Networks

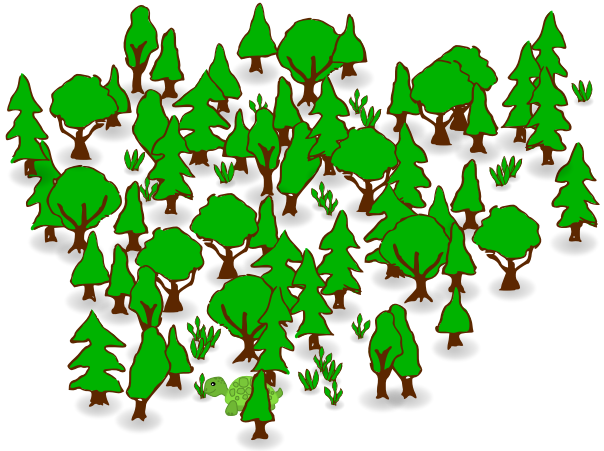
WSN Deployment

Requirements

- Unstructured deployment
  - Large scale environmental monitoring
  - Disaster scenarios
- Structured
  - Smart cities
  - Agricultural monitoring

Challenges

- Large deployments are cumbersome
- Terrain may be difficult
- Area may be dangerous



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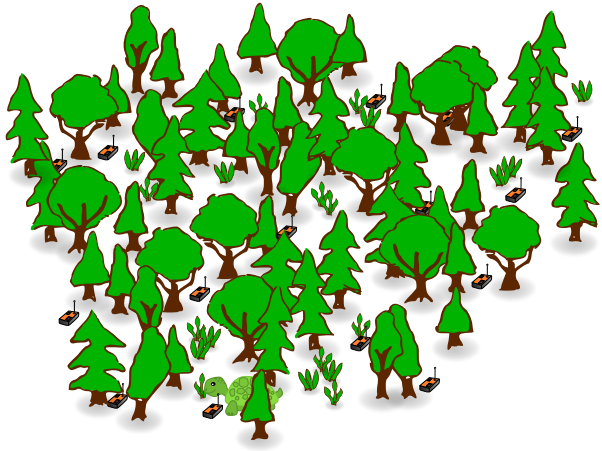

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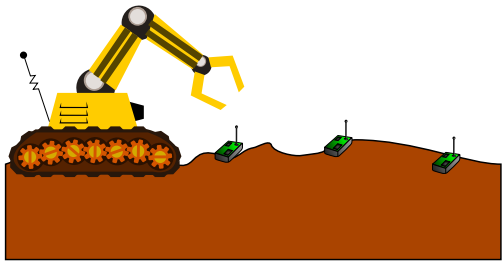

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- Ground Robots
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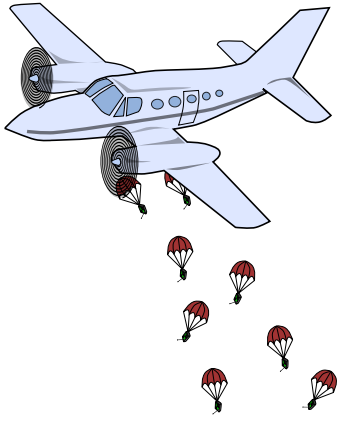
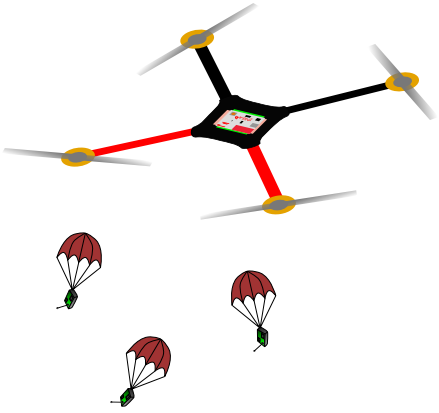
  - Terrain may be a problem, too
  - Indoor or outdoor
- Airplanes
  - Very expensive
  - Unstructured deployment
  - Never done



Deployment Methods

- Multicopters
  - Few sensors per UAV
  - Not suitable in dusty environments
  - Prone to wind
  - Short battery life



Deployment Methods

- Multicopters
  - Few sensors per UAV
  - Not suitable in dusty environments
  - Prone to wind
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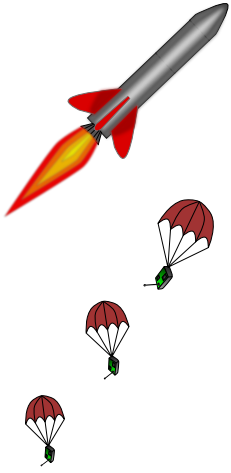
- Rockets
  - Very fast
  - Few nodes per rocket
    - But: Very cheap rockets
  - Easy to use



Deployment Methods

	Manual	Ground Robots	Airplanes	Multicopters	Rockets
Network Structure	Structured	Structured	Random	Structured	Random
Costs	Low	High	Very High	High	Low
Scalability	○	⊖	⊕	⊖	⊕
Haz. Environment	⊖⊖	○	⊖	○	⊕
Usability	⊕	⊖	⊖⊖	⊖	⊕⊕
Deployment Speed	○	⊖	○	⊖	⊕⊕

Scenarios suitable for rocket-based deployment

- Environmental Monitoring
- (Natural) Disasters
- Extraterrestrial WSNs
  - Robots on Mars are slow
  - Region which can be reached is small
  - They should be able to carry payloads
  - Multiple small rockets could be fired
  - Low gravity: small rockets needed

Rocket Design

- Rocket made of cardboard tube
  - 700 x 40 mm / 350 x 25 mm
- Tip and fins FDM-printed
- Weight: ∼120 g / ∼80 g

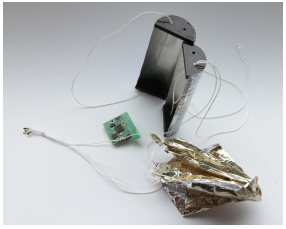
Motor	Impulse	Avg. Thrust	Burn	Delay
C6-3	9.6 Ns	6 N	1.6 s	3 s
D9-5	19.5 Ns	9 N	2.1 s	5 s

Used Motor types

Sensor nodes

Hardware

- Varieties of INGA sensor node
  - 8 bit Atmel AVR processor
  - AT86RF231 IEEE 802.15.4 radio
  - Button cell
  - Weight: ∼8 g



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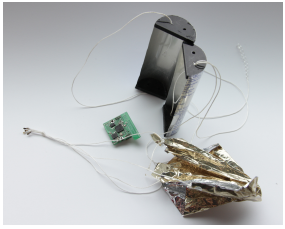
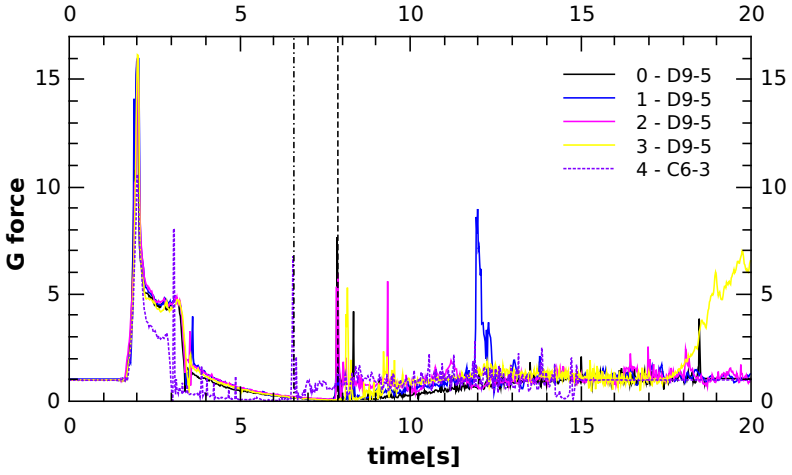


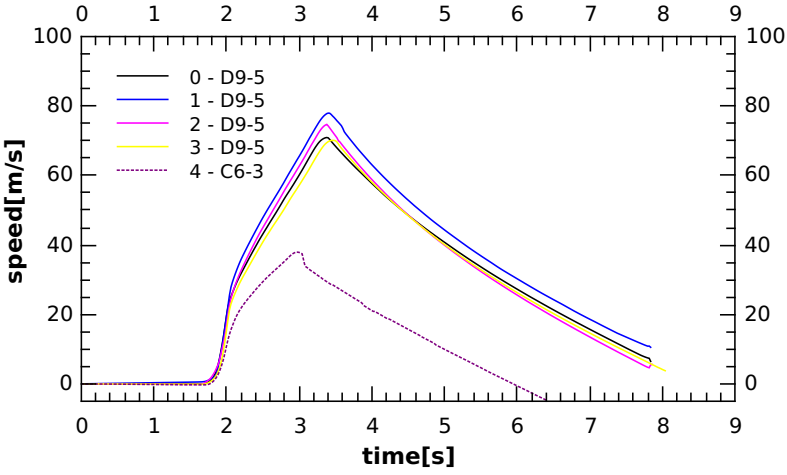
Distribution

- Parachutes and strips made of space blanket
- Ejection
  - Nodes stuffed
  - Sleds made of aluminium
  - Housing made of PLA

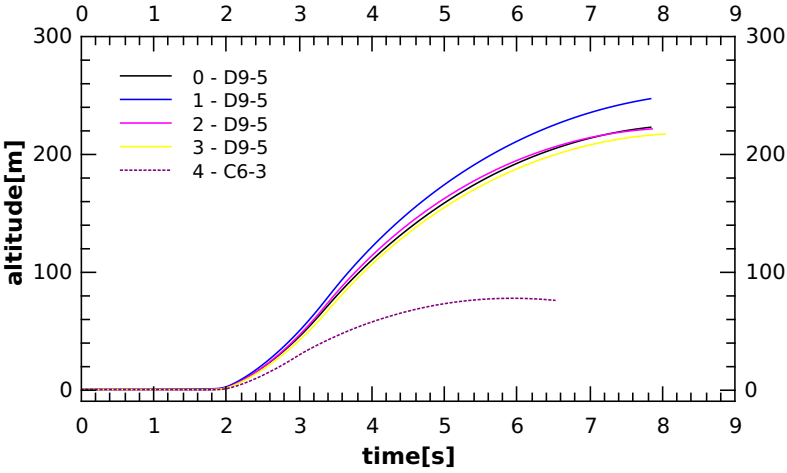
Flight Metrics: G forces



Flight Metrics: Speed



Flight Metrics: Altitude

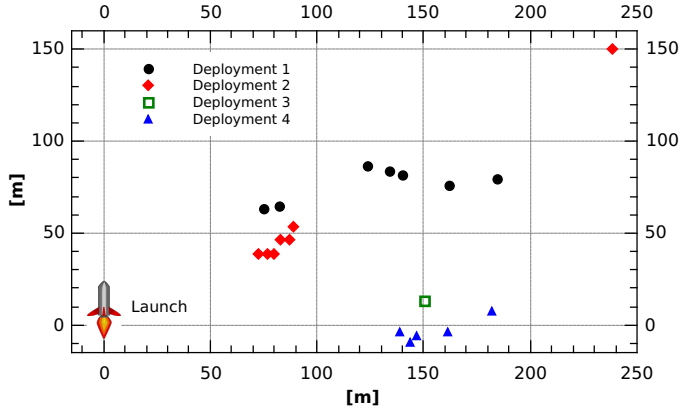


Deployments

#	Rocket	Engine	Node Enclosure	Parachute
1	large	D9-5	Mylar & Sleds	yes
2	large	D9-5	Plastic Enclosures	no
3	small	C6-3	Plastic Enclosures	no
4	large	D9-5	Plastic Enclosures	no

List of Deployments

Deployment results



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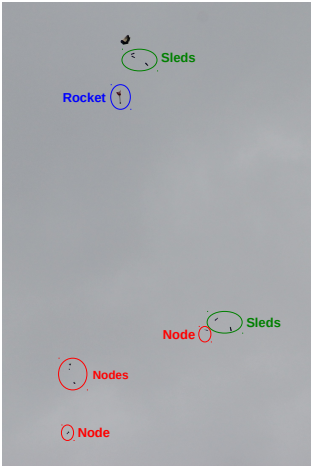


Flight metrics

- Altitude 120-250 m
- Acceleration 10-15 g
- Maximum distance at 45°:
  - Large rocket, C6-3: 171 m
  - Large rocket, D9-5: 370 m

Deployment

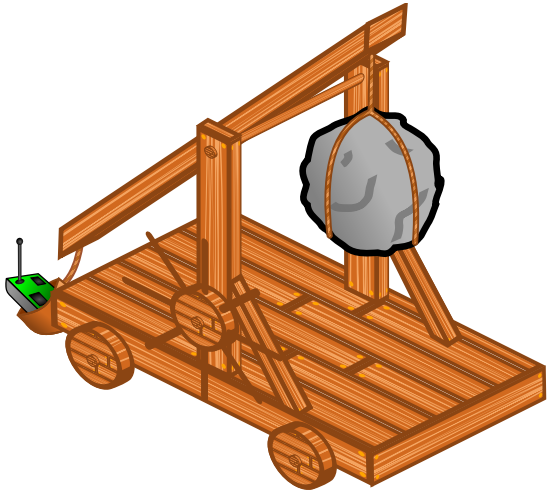
- Structure not easily predictable
  - Sometimes concentrated, sometimes in a line
- Deployment depends on ejection, wind, parachute, …

Problems during experiments

- Stuffing with parachute
  - High density
  - Nodes get stuck in tube
  - Condensed subterranean deployment
- Rocket ~~may~~ will end up in tree
- Nodes and rocket are hard to find

Discussion

- Environmental aspects
  - Batteries
  - ...are also required using other methods
- Other ballistic approaches
  - Loaded spring
  - Slingshot, crossbow, ...
- Connectivity
  - Not guaranteed in any case
  - DTN like protocols needed
  - Data mules



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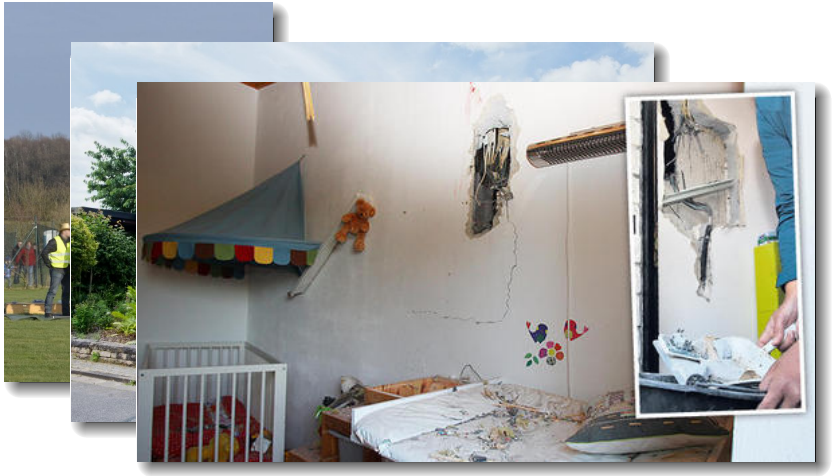

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Benefits

- Fast
- Works at any time
- No dead batteries
- Extremely cheap
- Easy to use
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Thank you!

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