Parallelizing On-Board Data Analysis Applications for a Distributed Processing Architecture

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Overview

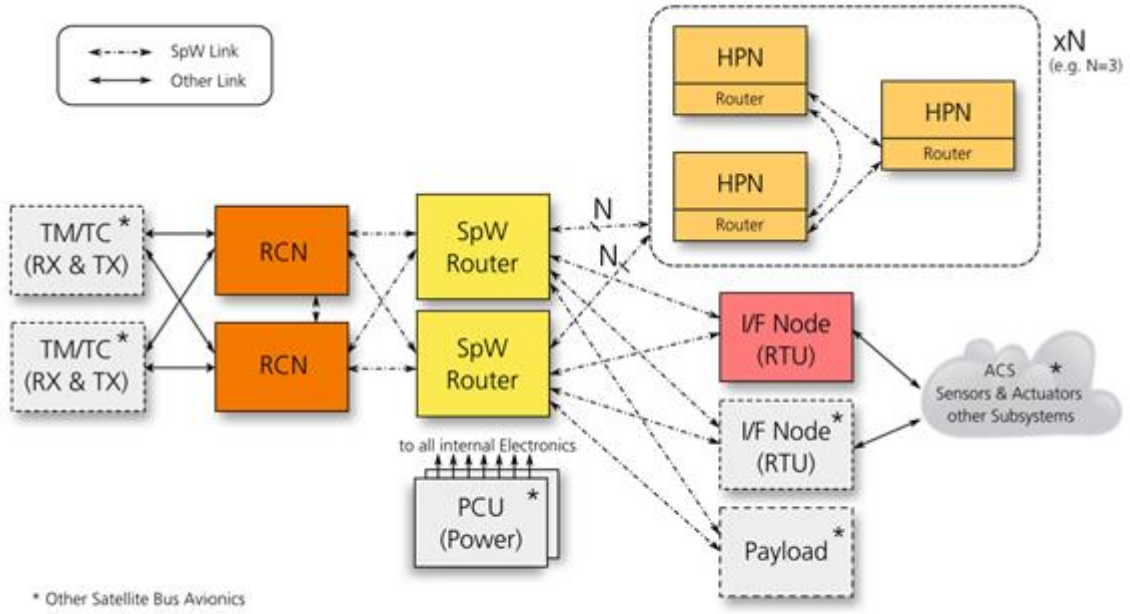
- Aim
  - Increase throughput of on-board data analysis
- Application
  - Real-time information system
  - Neural-network-based image processing
- Approach
  - Coarse-grained parallelization
  - Distributed system
  - COTS CPUs
  - Based on ScOSA and ODARIS systems from DLR
- Advantages
  - Algorithm agnostic
  - Scalable
  - Applications run in software

Background

- Satellites are producing large quantities of data
  - Earth observation
  - Multi-spectral imaging
  - On-board autonomy
- Real-time applications
- Downlink rates limit ground-based processing
- Space-grade processors too slow

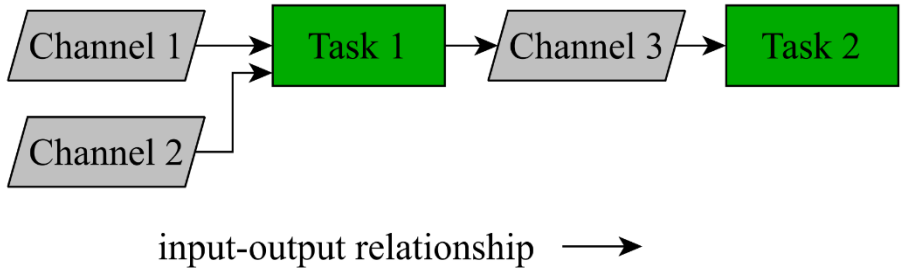
ScOSA

- Scalable On-Board Computing for Space Avionics
- Distributed computer
- High-performance COTS processors
- High-reliability space-grade processors
- Middleware for convenient use
- SpaceWire and Ethernet support
- RTEMS and Linux support



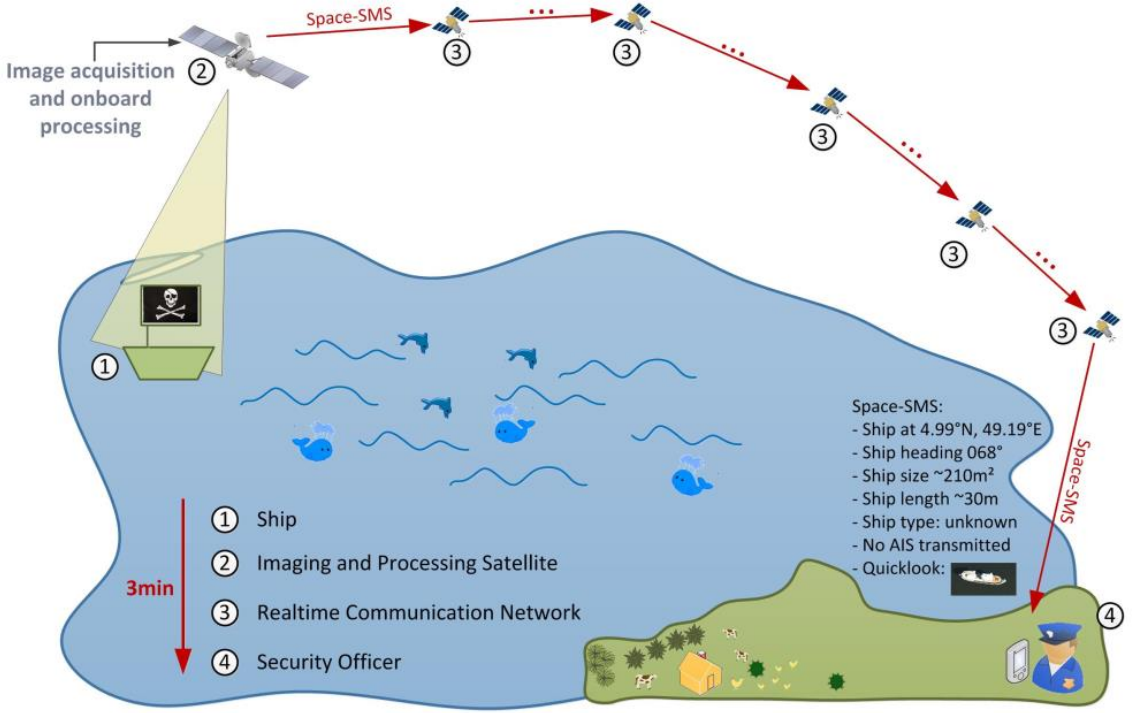
Tasking Framework

- Data-flow paradigm
  - Tasks
  - Channels
- Distributed execution
- Easy parallelization



ODARIS

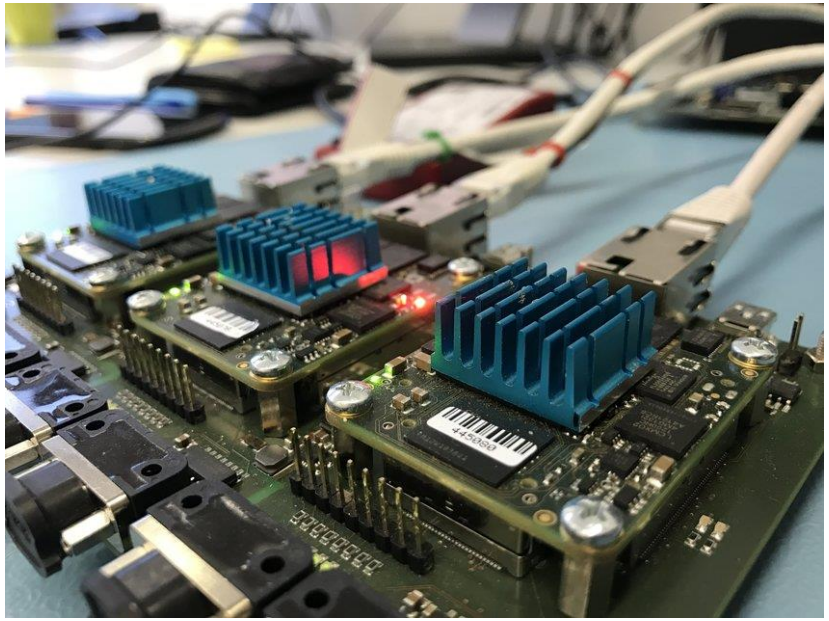
- On-Board Data Analysis and Real-Time Information System
- On-board analysis of sensor data
  - Machine learning
- Information service
  - Query-based user requests
  - Event-based push notifications
- Low-latency communications
- Multiple possible applications
  - Detection of clouds, icebergs, ships



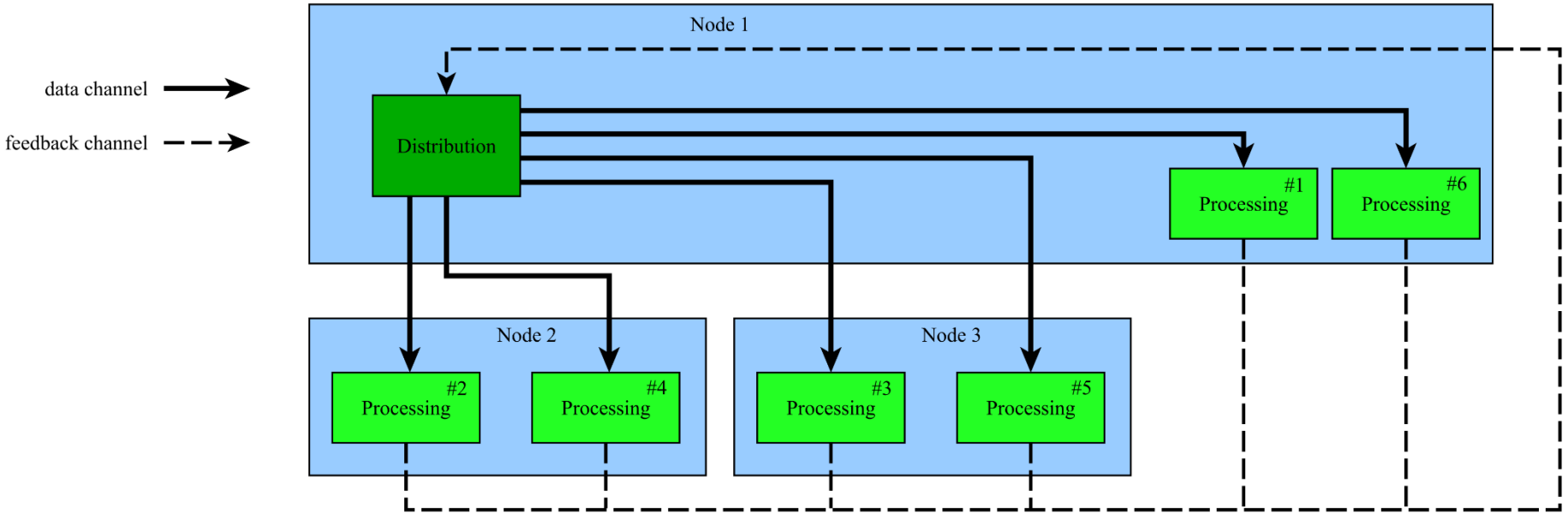
Schwenk, K., Willburger, K., & Pless, S. (2017). Amaro-autonomous real-time detection of moving maritime objects: Introducing a flight experiment for an on-board ship detection system. *Earth Resources and Environmental Remote Sensing/GIS Applications VIII*, *10428*, 1042808. https://doi.org/10.1117/12.2277991

Experiment

- 3x Xilinx Zynq-7020 SoCs
- Ethernet connection
- Image classification
  - Convolutional neural network
  - TensorFlow Lite MobileNetV1
  - 4 threads

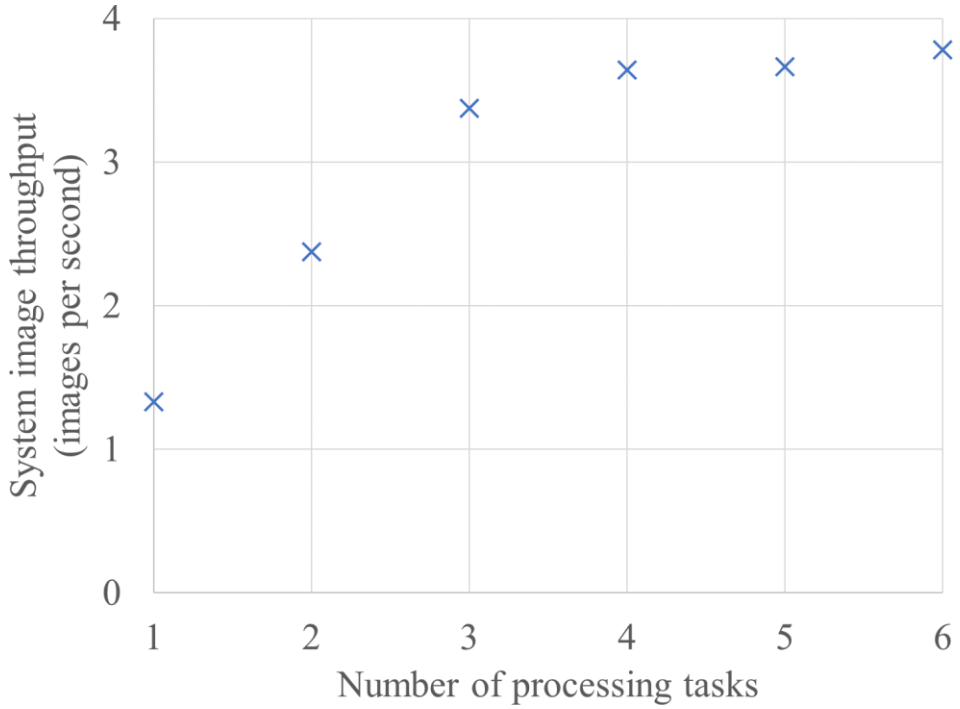


Task-Node Structure



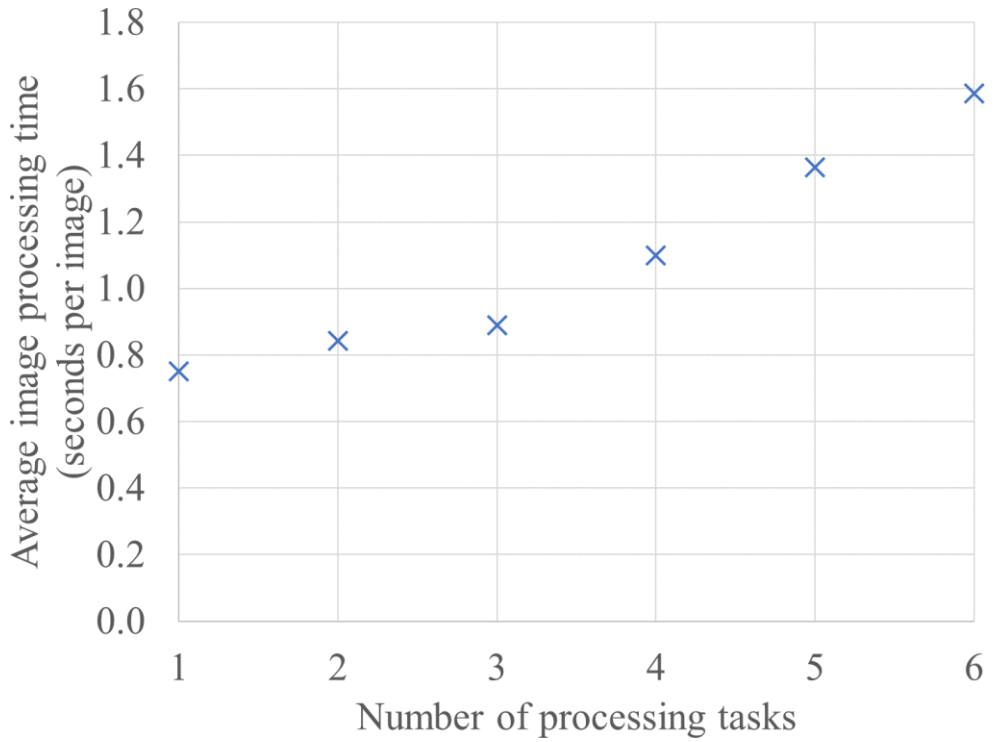
Results: Processing throughput

- 2.5 times speed up with 3 tasks and 3 nodes
- Little further improvement with 6 tasks and 3 nodes (tasks are already multi-threaded)



Results: Processing time

- Acceptable overhead with 1 task per node
  - 19% longer processing time
- 2 tasks per node causes significant slowdown

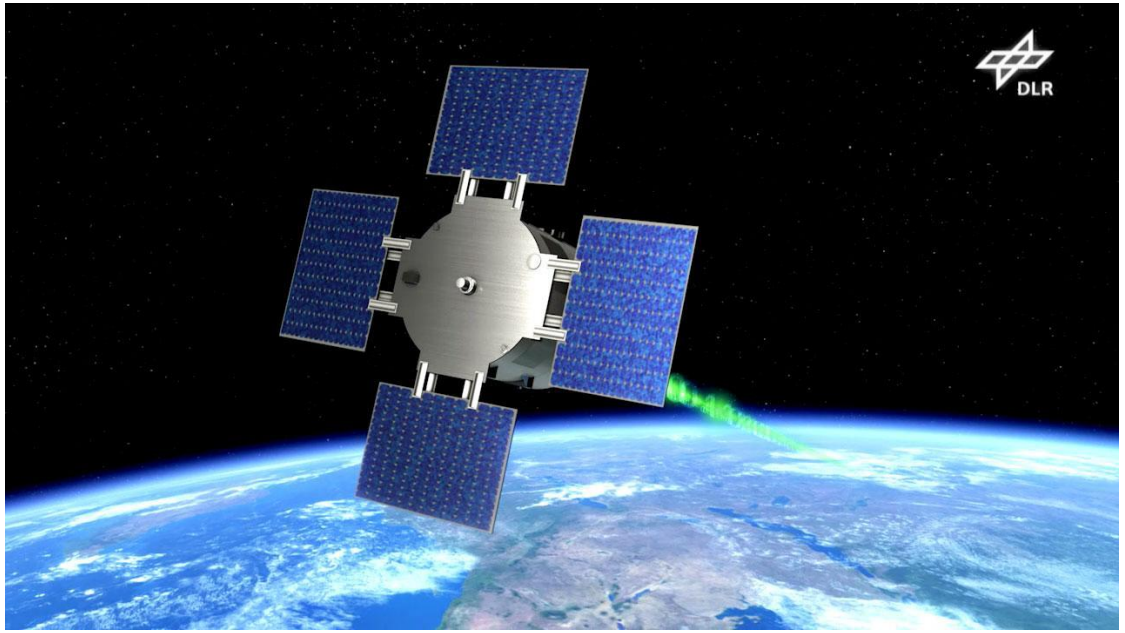


Conclusions

- ScOSA system allows
  - coarse-grained parallelization of processing intensive tasks
  - significant speedup possible
  - scalable by adding processors
- No in-depth algorithm knowledge required
  - Low implementation effort for application developers
  - Possible with black-box algorithms

Future Work

- Deployment to ESA OPS-SAT
- Deployment to DLR Compact Satellite
  - Further hardware development in progress
- Integration with other ODARIS components
  - TM/TC
  - Low-latency satellite communication
  - Application-specific data processing



Previous DLR Compact Satellite Mission Eu:CROPIS

DLR - Dossier zur Mission Eu:CROPIS. (o. J.). MISSION DLR Portal. Abgerufen 9. Juni 2021, von https://www.dlr.de/content/de/missionen/eucropis.html