The UniBoard

a RadioNet FP7 Joint Research Activity

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Overview

- Background, project setup
- Current state
- UniBoard as SKA phase 1 correlator/beam former
- Future: UniBoard²
The aim

- Creation of a multi-purpose scalable high-performance computing platform for radio astronomy
- Originally proposed by Sergei Pogreb in the late 90s, as a single-board all-station correlator, became basis of project in
- Combine as much CPU and as much I/O as possible on a “reasonably” sized board (Pogrebko melt-down criterium)
- Use standard interfaces as much as possible
- Only digital, nothing analog...
- Develop several different applications at the same time, force design to be as generic as possible
The project

- **UniBoard**: a RadioNet FP7 Joint Research Activity, 9 partners, kicked off January 2009

- **JIVE**: project lead, VLBI correlator
- **ASTRON**: hardware development, test firmware
- **INAF, University of Bordeaux**: digital receiver
- **University of Manchester**: pulsar binning machine
- **University of Orléans**: RFI mitigation algorithms
- **KASI**: VLBI correlator

- **ShAO**: digital receiver, VLBI correlator
- **University of Oxford**: all-dipole LOFAR correlator

- Strong support from collaboration, large amount of matching effort, financial contribution
Supporting projects

• ExBox: Expandable Box for X-correlation
  • JIVE/ASTRON proposal to NWO

• Build prototype FPGA EVN/APERTIF correlator
  • Using LOFAR expertise and technology
  • Backplane with several boards
  • Matching funds for UniBoard

• NWO - ShAO collaborative agreement
  • Stimulate collaboration between JIVE and ShAO in the development of FPGA-based correlators and VLBI space science applications
  • Several positions: students, postdoc, engineer

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The design

- 14 Layers
- 340x366mm
- 7304 components (47% of board space in use)
- 25798 connections
- 271 meter traces
The result

- Per board: 8 Altera Stratix IV FPGAs (40 nm, 1288 18x18 multipliers, 400MHz, ~0.5TMAC/s)
- Per FPGA: 2 DDR3 memory banks (on backside of board)
- Four times four 10-GbE links connect to the front nodes via four SFP+ cages
- High speed mesh connects each front node to all back nodes
- The back nodes in their turn connect via four times four 8-bits LVDS to a backplane connector
- A 10G break-out board (the XGB) has been designed in the form of a mini-backplane, with a total of 16 CX4 connectors
- Prototype delivered May 2010, production run completed

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Applications under development

• **Currently under development:**
  - VLBI correlator (JIVE)
  - digital receiver (INAF, BORD)
  - pulsar binning machine (UMAN)
  - RFI mitigation (UORL)

• **Coming soon:**
  - APERTIF correlator (ASTRON)
  - APERTIF beam former (ASTRON)
  - AARTFAAC all-dipole LOFAR correlator (ASTRON + University of Amsterdam)
  - all-dipole LOFAR correlator (Oxford)
  - ShAO 65 meter telescope backend
  - Chinese/Korean VLBI correlators
  - more applications on the way

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Current effort in Dwingeloo

- Hardware design: Gijs Schoonderbeek, Sjouke Zwier
- Test firmware (+ testing): Eric Kooistra, Daniel van der Schuur, Jonathan Hargreaves

- Board control, correlator control system: Harro Verkouter, Des Small
  - Written in Erlang
- VLBI correlator firmware: Jonathan Hargreaves, Salvatore Pirruccio, Jintao Luo
Different configurations

- Combination of UniBoards into larger systems via backplane

- Will be developed through NWO-funded ExBox project

- Application in APERTIF (ASTRON)
  - Correlator for 12 dual pol dishes, 300 MHz bandwidth, 37 beams

- Application in AARTFAAC (University of Amsterdam-ASTRON collaboration)
  - Correlator for 576 signal paths, \( \sim 17.5 \) MHz bandwidth

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SKA mid-frequency correlator (1)

Mid-frequency:

- 256 telescopes
- single pixel feeds
- 1024 MHz instantaneous bandwidth
- 2 pols
- 8 bits representation
- 7.5 kHz maximum resolution
- 0.1 s minimum dump time
SKA mid-frequency correlator (2)

- Make use of excellent switching capability of UniBoard
SKA mid-frequency correlator (3)

- 384 boards
- ~170 kW
- ~3.8 Meuro
- Feasible…
SKA low-frequency beam former

Low-frequency:

- Number of stations: 50
- Number of polarisations: 2
- Number of antennas / station: 11200
- Input bandwidth: 500 MHz
- Output bandwidth: 380 MHz
- Number of beams: 160
- Number of input bits from the station ADC: 8
- Number of output bits to the correlator: 4 x 2
- Subband width: 125 kHz
- Channel width: 1 kHz
SKA low-frequency correlator

- 50 stations, 160 beams
- (correlation + beam forming)
- 9414 boards
- 90 Meuro
- 3.3 Mwatt

But, *currently* available hardware
- ~2 generations of FPGA until 2015

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Next: UniBoard²

- Possible Joint Research Activity in RadioNet³, follow-up of current project, start date 2012 (if approved by EC) (looking good)
- Received strong support from RadioNet community
- Same basic idea, development of generic hardware complemented by a number of applications
- Consolidate and build on expertise obtained through UniBoard project
- **Strong emphasis on power efficiency (green computing)**
- Production-ready in 2015/2016

- **Complete re-design, using the next generation 28 nm FPGAs**, possibly one generation beyond that (some slack in start date of project)
- **Non-leded components**
- Possible use of **40GE, 100GE**
- Investigation into effects of **hard-copy** and **partial hard-copy**
- **Tuning of algorithms and firmware design** to minimize power consumption
- **Balancing of system parameters and performance** to minimize power consumption
- **Standardized interfaces and coding conventions** to facilitate sharing and re-use of firmware blocks among developers of different applications

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