SKA-Related Activities in Korea

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SWG

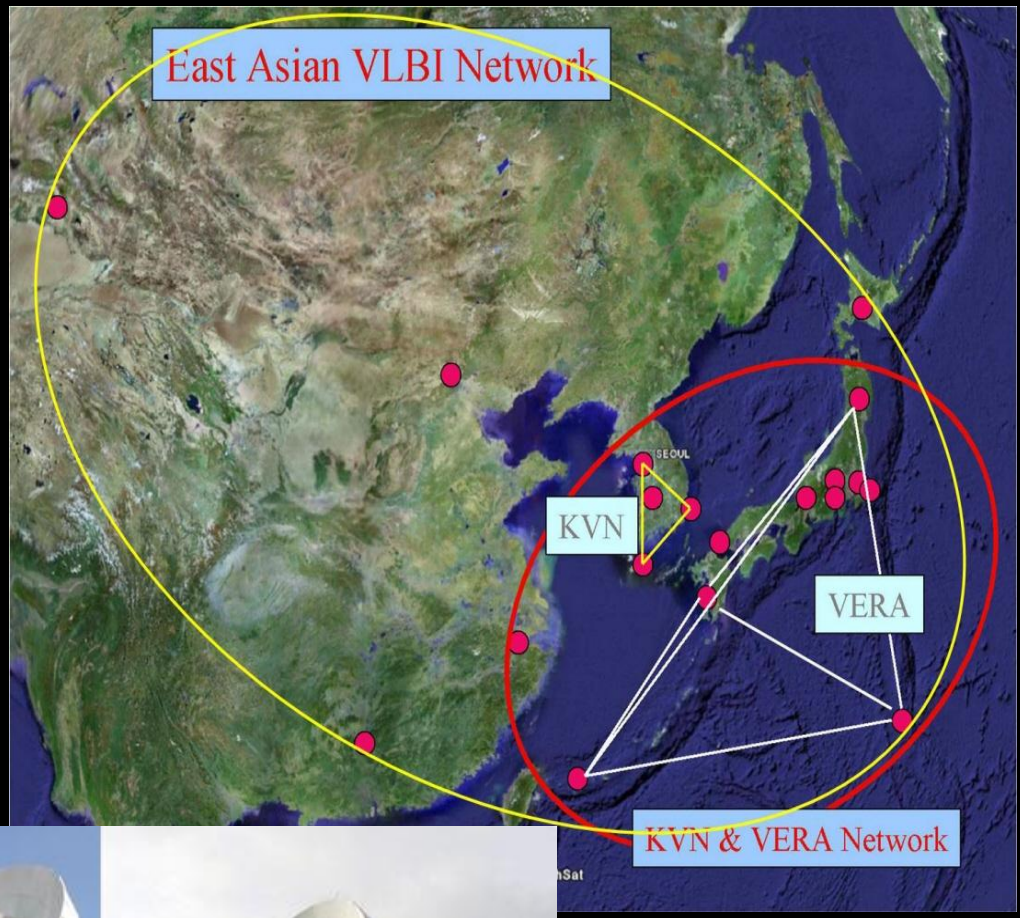
- members
  - young astronomers
  - theory+observation
- sciences
  - H I
    (dark age, galaxies, the ISM)
  - Cosmic Magnetism
    (intergalactic, interstellar B-fields)

IWG

- High Gain Antenna

  KVN: 3 21m ants.

  22,43,86,129 GHz



IWG

- KEPCO (Korea Electric Power Corporation) + LG, SKT, KT, and Samsung

  Smart Grid Test-bed in Jeju Island

Correlators for Radio Interferometry

- ASIC (Application-Specific Integrated Circuit)
- FPGA (Field-Programmable Gate Arrays)
- Software (high level-languages, e.g., C/C++)
  - Rapid development
  - Expandability
  - …

Current Status of SC

- LBA (Australian Long Baseline Array)
  - 8 antennas (Parkes, … 22-64m, 1.4-22GHz)
  - DiFX software correlator (2006; Deller et al. 2007, 2011)
- VLBA (Very Long Baseline Array)
  - 10 antennas (25m, 330MHz - 86GHz)
  - DiFX
- MPIfR (the Max Planck Institute for Radio-astronomy)
  - Mark4 → DiFX

Current Status of SC (cont.)

- GMRT (Giant Metrewave Radio Telescope)
  - 30 antennas (45m, 50MHz-1.5GHz), 32MHz
  - ASIC → software correlator (Roy et al. 2010)
- LOFAR (Low Frequency Array)
  - LBA (Low Band Antennae) 10-90MHz
  - HBA (High Band Antennae) 110 – 250MHz
  - IBM BlueGene/P: software correlation

CoDR for SKA Phase I, Memo 125

- Key Sciences: H I and Pulsars
- Sparse Aperture Array

  70-450 MHz, A/T_{sys} = 2000m^2/K, L_{max}=100Km
- Dish Array

  0.45-3 GHz, A/T_{sys}=1000m^2/K, 250 15m dishes single-pixel feeds, L_{max}=100Km
- Construction: 2016-19
- Budget: 350M Euros

Correlation Theorem, FX-correlator

$$R_i(f) = \int_{-\infty}^{+\infty} r_i(t) \mathrm{e}^{2\pi i f t} dt$$

F-step (FT):
~$\log_2(N_c)$ operations per sample

$$\int_{-\infty}^{+\infty} r_j(\tau + t) r_j(\tau) d\tau \Leftrightarrow R_i(f) R_j^*(f)$$

X-step (CMAC):

~ N operations per sample

FLOPS of the X-step in FX correlator

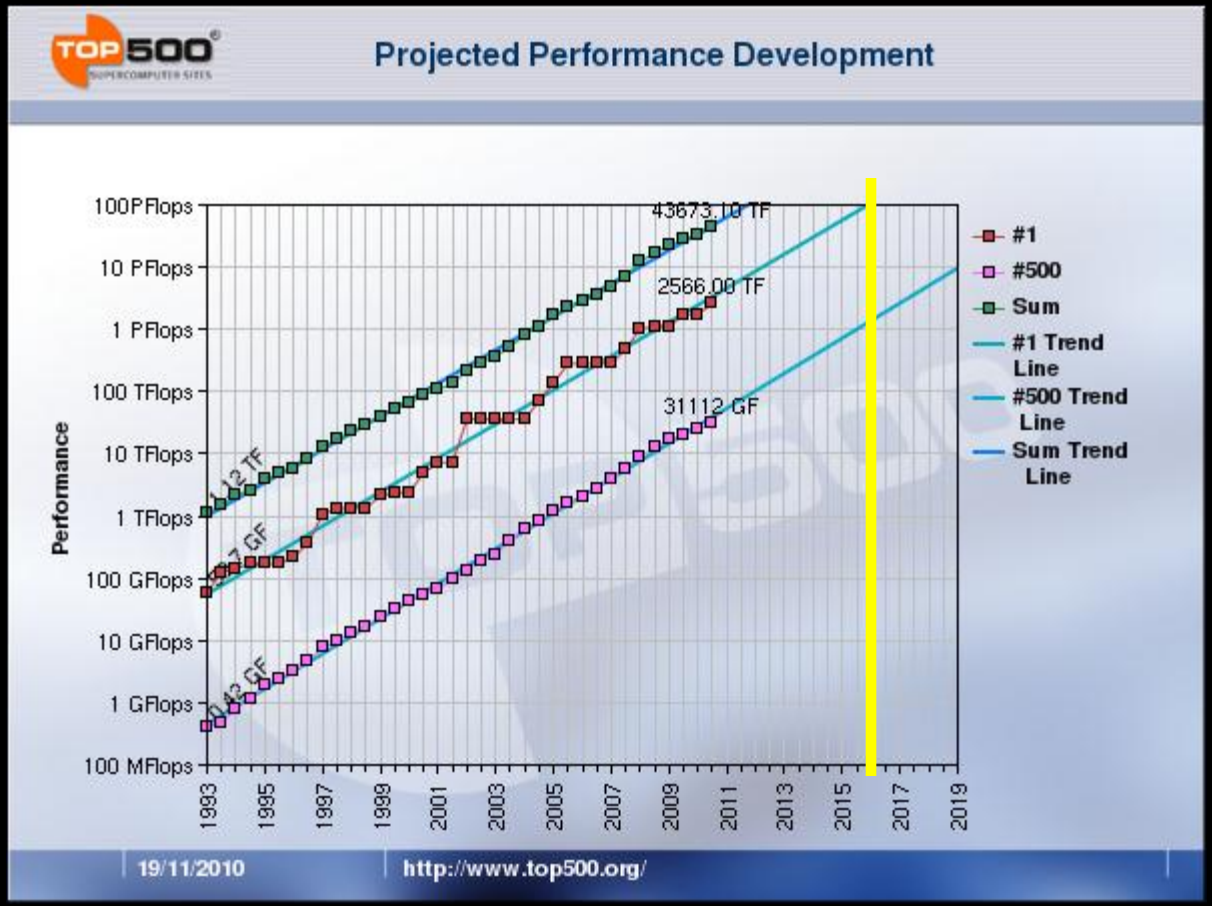
$$4 \times 8 \frac{N(N+1)}{2} N_b \left(\frac{B}{\mathrm{Hz}} \right) [\mathrm{FLOPS}] \approx 16 N^2 N_b \left(\frac{B}{\mathrm{GHz}} \right) [\mathrm{GFLOPS}]$$

- 4 is from $R_i R_j^*, R_i L_j^*, L_i R_j^*, L_i L_j^*$
- 8 is from 4 multiplications and 4 additions:

$$+R_i R_j^* = +(a_i + ib_i)(a_j - ib_j) = +(a_i a_j + b_i b_j) + i(b_i a_j - a_i b_j)$$

- $N(N+1)/2$ is the number of auto- and cross-correlations with antenna (station) N
- Dish array (N=250, B = 1 GHz, N_b=1)
  → 16×250^2 GFLOPS = 1 PFLOPS
- Sparse AA (N=50, B=380MHz, N_b=160)
  → $16 \times 50^2 \times 160 \times 0.38$ GFLOPS = 2.43 PFLOPS

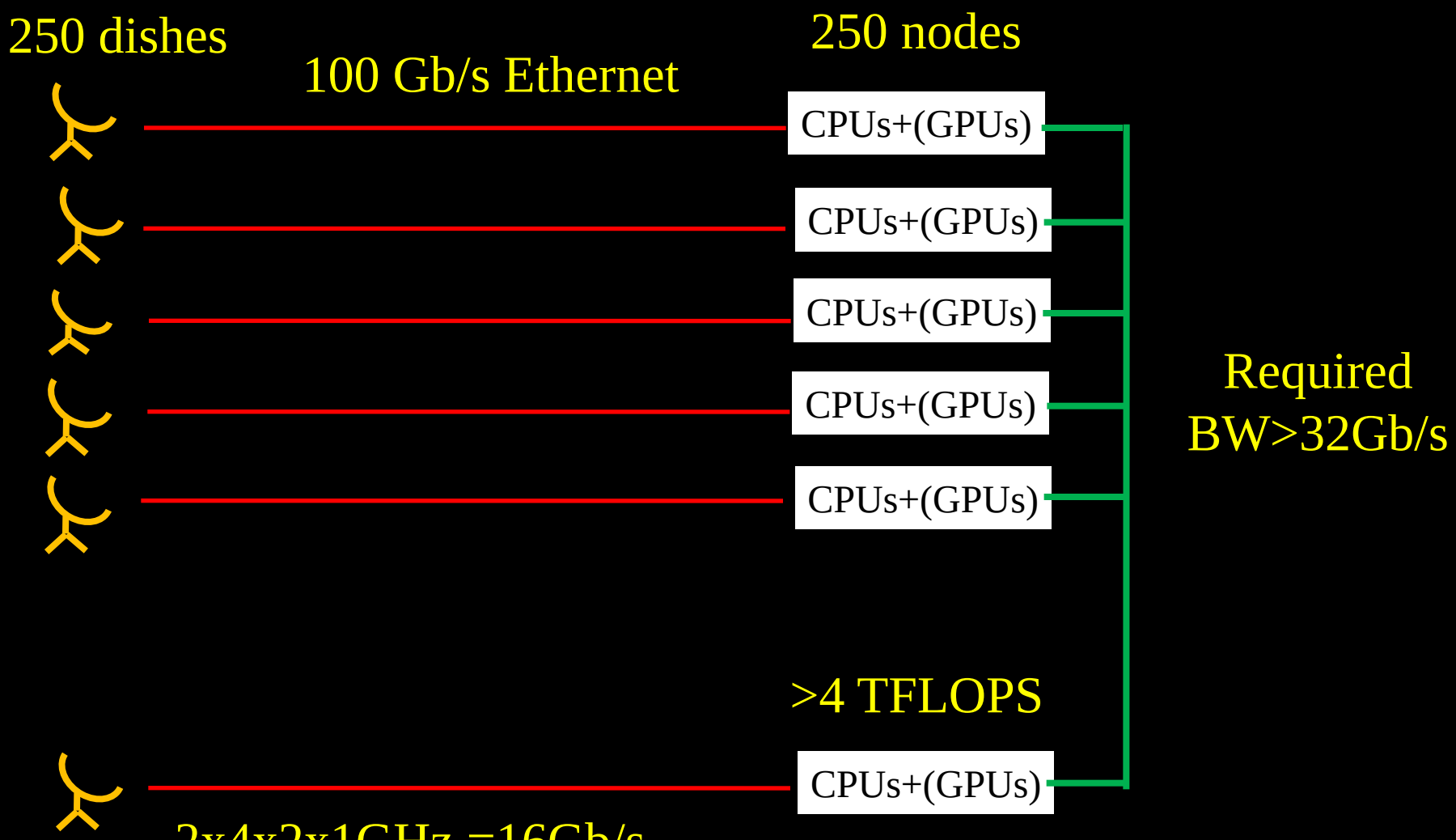
top500


TOP500
Projected Performance Development
100 PFlops
10 PFlops
1 PFlops
100 TFlops
10 TFlops
1 TFlops
100 GFlops
10 GFlops
1 GFlops
100 MFlops
Performance
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
2019
43673.10 TF
2566.00 TF
31112 GF
#1
#500
Sum
#1 Trend Line
#500 Trend Line
Sum Trend Line
19/11/2010
http://www.top500.org/

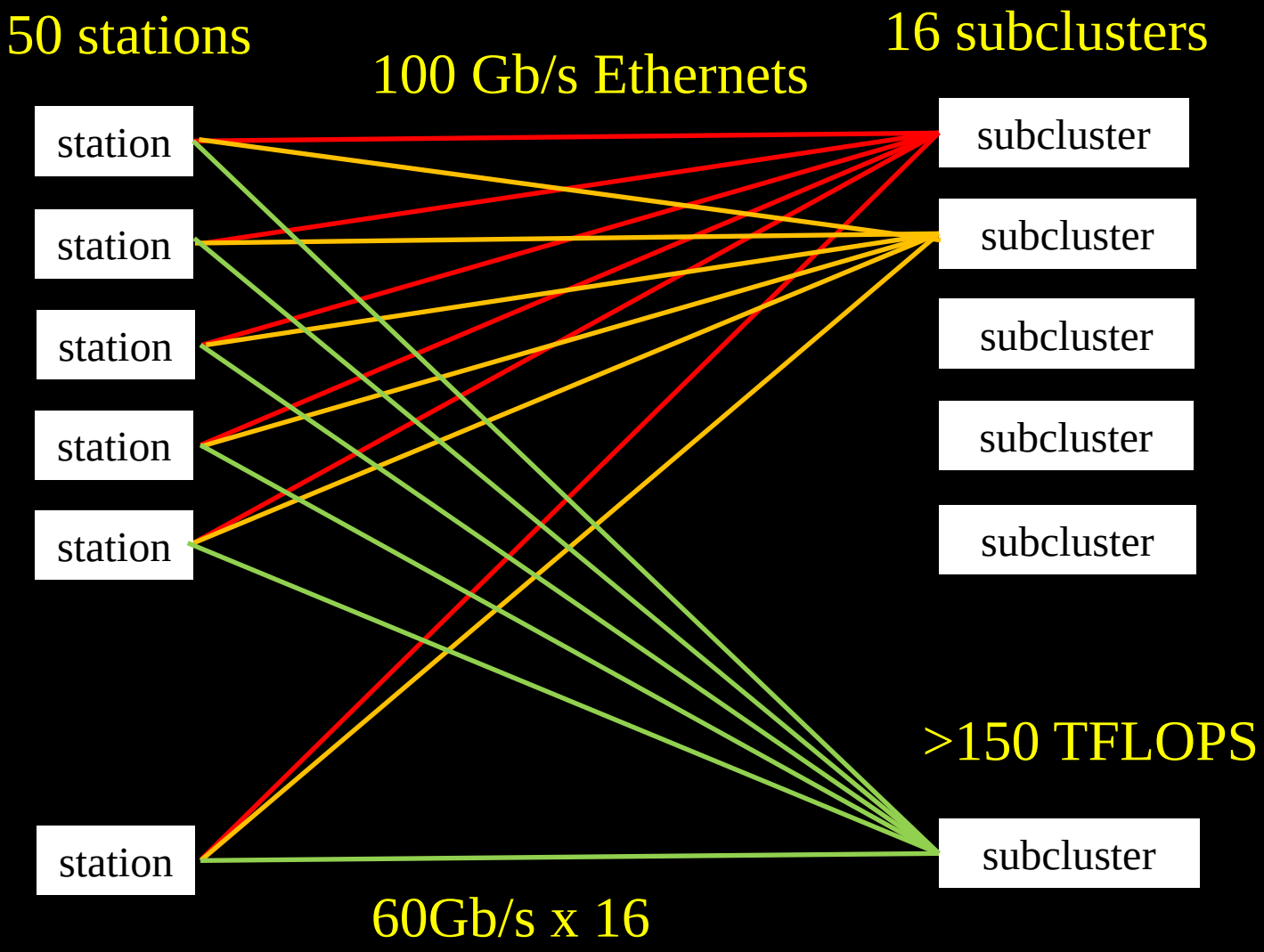
Design goals

- Connect antennas and computer nodes with simple network topology
- Use future technology development of HPC clusters
- Simplify programming

CoDR of a Software Correlator for the dish array



CoDR of a Software Correlator for the sparse AA



Cost and Power Estimates of SCs

	# of nodes	Cost per node [kEuros]	Cost of IB per port [kEuros]	Power per node [kW]	Total cost [M Euros]	Total power [MW]
Dish Array	250	5	1	1.0	1.5	0.25
Sparse AA	800	5	1	1.0	4.8	0.80
Total	1050				6.3	1.05

Conclusions

- SWG, IWG
  - Korea has a potential to contribute the SKA community.
- Software correlators
  - One cluster with 1 PFLOPS for the dish array.
  - 16 clusters, each cluster with 150 GFLOPS, for the sparse AA.