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SKA Activity Report

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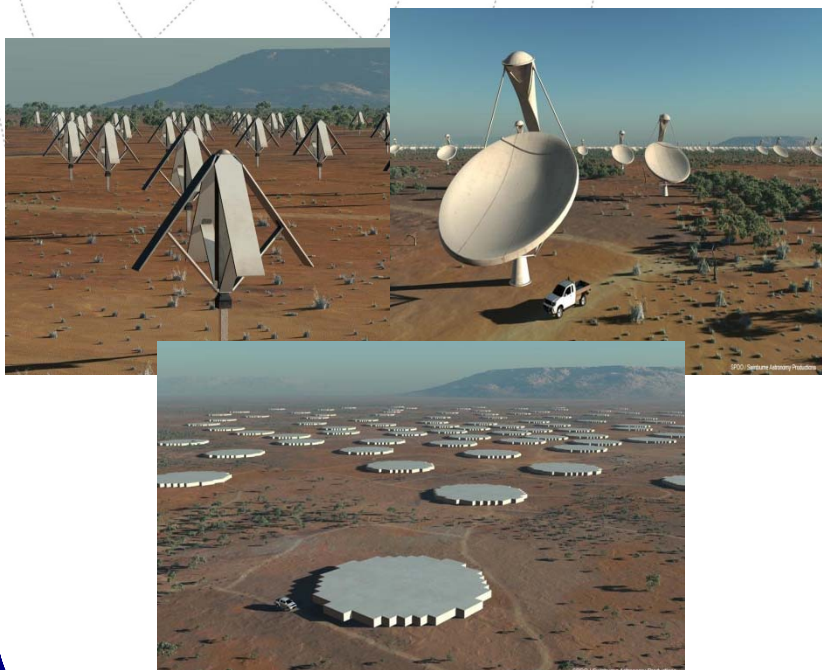
PT Inovação

SIEMENS Communications

instituto de telecomunicações

creating and sharing knowledge for telecommunications

Signal Transport for SKA : from antenna to station to correlator



- Terabits of data ; very high traffic (200x WIT 2009)
- Time critical transmission (response of telescopes), requiring minimal delay
- Wide Spread Areas, continental sizes.
- Missing or minimal infrastructure
- Service: building, maintaining, operating

Signal Transport for SKA : from antenna to station to correlator

- **Huge progress in available technology**
- 9.6Tbps with 100G per channel
- Synchronization options with low delay and jitter
- Up to 2500km without regeneration-> less equipment
- High degree level of automation

Signal Transport for SKA : from antenna to station to correlator

- Choose future-proof technology, easily upgradable and scalable
- Choose and install fiber infrastructure
- Choose how to build and minimize maintenance, and operating costs
- Guarantee low cost/bit

StaN related visits/workshops:

- Feb 2010 (Lisbon) - AAVP visit @ Nokia Siemens Networks (NSN) Portugal.
- May 2010 (Lisbon) - AAVP, SPDO, IT, CICGE ; @ NSN
- Sep 2010 (Aveiro) - 4th Radionet Enginering Forum Workshop ; with presence of Eriksson, NSN, SPDO, South Africa, Europe.

- Overview of existing technology; on custom made for radioastronomy vs general industry driven products
- Forecast on industry standards and plans --> discussion on availability of high-performance components & parts for SKA systems within SKA timeframes.
- I/O impact on antenna and correlator buffers.

Contents

- **What are the nonfunctional requirements for the SKA in terms of:**
  - Network Management
  - Swappable Units
  - Line-Side and Client-Side Interfaces
- **40G Transmission vs 10G?**
  - Commercially availability today
  - Market Drivers
  - Technical Issues
  - Cost & Power drivers?
- **Higher Transmission rates, ie 100G?**
- **Green energy powered? Self-sustainable?**

Contents

- Work developed at IT, in the framework of the PrepSKA FP7 Consortium, GRIT (IT's RadioAstronomy Group) and the Optical Communications Group at IT (Aveiro), for the Square Kilometer Array (SKA) project.
- Phase 1 Scenarios and Simulations
- Phase 2 Scenarios and the need for infrastructure developments

Nonfunctional Requirements

- The following slides describe the nonfunctional requirements for the SKA.
- In order to achieve them, an intensive research of today's commercially deployed and available technologies in the market was made.
- More than 20 companies were found, which provided all the information on their products needed for this study.
- A complete list of the standardized technologies and their features was created and through that list it was possible to define the main requirements for the SKA.

Network Management

- Network management is essential to ensure efficient and continuous operation of any network.
- The table below describes the main requirements in terms of network management for the SKA.

Automatic Fault Recovery	Isolation, Protection and Recovery	Management layer interfaces
Channel Monitoring Channel Optimisation	EN 300 386 EMC	SNMP interface CRAFT interface TL1 interface
Alarm Reporting	EN 55022 - Radiated emissions	Ethernet interface RMON interface
Fault Isolation	EN 61000-3 Harmonic current emissions	Automatic switching/ Multi section protection ASP/MSP
Display and Access	EN 61000-4 Radiated immunity	G.709 Interface

Network Management

- Each main requirement of the previous table has several sub-requirements to be considered for the SKA.
- Taking Channel Monitoring from Automatic Fault Recovery as an example:

Automatic Fault Recovery
Channel Monitoring →
Channel Optimisation
Alarm Reporting
Fault Isolation
Display and Access

Channel Monitoring
Laser bias current
Laser temperature
Transmitter optical output power
Receiver optical input power
Central wavelength
Auto wavelength discovery
Optical Signal to Noise

Swappable Units

- Scalable capacity, faster provisioning, spare management and low costs are some of the SKA demands. The following table lists some of the ways to achieve them.

Swappable Units
Replacement of units under power (hot swappable) Field replaceable units Pluggable, interchangeable, and tunable units
Local configuration and upgrade capacity Remote configuration and upgrade capacity
Scalable number of channels Self tune capability when new wavelength channels added Any mix of services on a single card
Scalable line speeds 10G to 40G, 40G to 100G and 10G to 100G

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Line-Side and Client-Side Interfaces

- Depending on the implementation scenario of the SKA, the table below shows possible configurations for the line-side and client-side interfaces.

Data Rates	Protocols	Modulation Formats	Optics
• 10G • 40G • 100G	• SONET/SDH: OC-48/ STM-16, OC-192/ STM-64, OC-768/ STM-256 • G.709 OUT-2/-3 • Gigabit and Fast Ethernet • 10GE WAN/LAN PHY • ESCON, FICON • 10G Fibre Channel	• Optical DuoBinary • RZ, NRZ • DPSK, DQPSK • RZ-DPSK, NRZ-DPSK • RZ-DQPSK • Coherent PMD-QPSK • Coherent CP-QPSK	• Pluggable XFP • Pluggable SFP

- Continued growth of bandwidth and the pressure to reduce transmission costs will lead to the need for higher bit rates, and consequently, new protocols and modulation formats.
- For the SKA it will not be an exception, and for that, the equipment must have specific features.

Line-Side and Client-Side Interfaces

- All the features for the line-side and client–side interfaces were listed but in the following table, only some of them are described due its high number.

Line-Side Features	Client-Side Features
• CWDM and DWDM Transport • Forward Error Correction (FEC) and Enhanced FEC • Coherent Detection • PMD and CD tolerance and DCM free optical design • 3R operation (reshape, retime, regenerate) • Remote access and highly effective automation • Full band tunable transponders and transceivers • 10G, 40G, 100G transponders • Mix of services in one card • Common line cards and chassis • Regenerator functionalities • National, regional, metro reach	• Multi-port, multi-protocol transponders with per-port service selectivity • Multiplexing transponders to support asynchronous multiplexing • Software programmable ports on the muxponders • ITU application codes G.691 I-64.1 (GR-253 SR-1) • Multirate multireach client interfaces

A look into High transmission rates ?

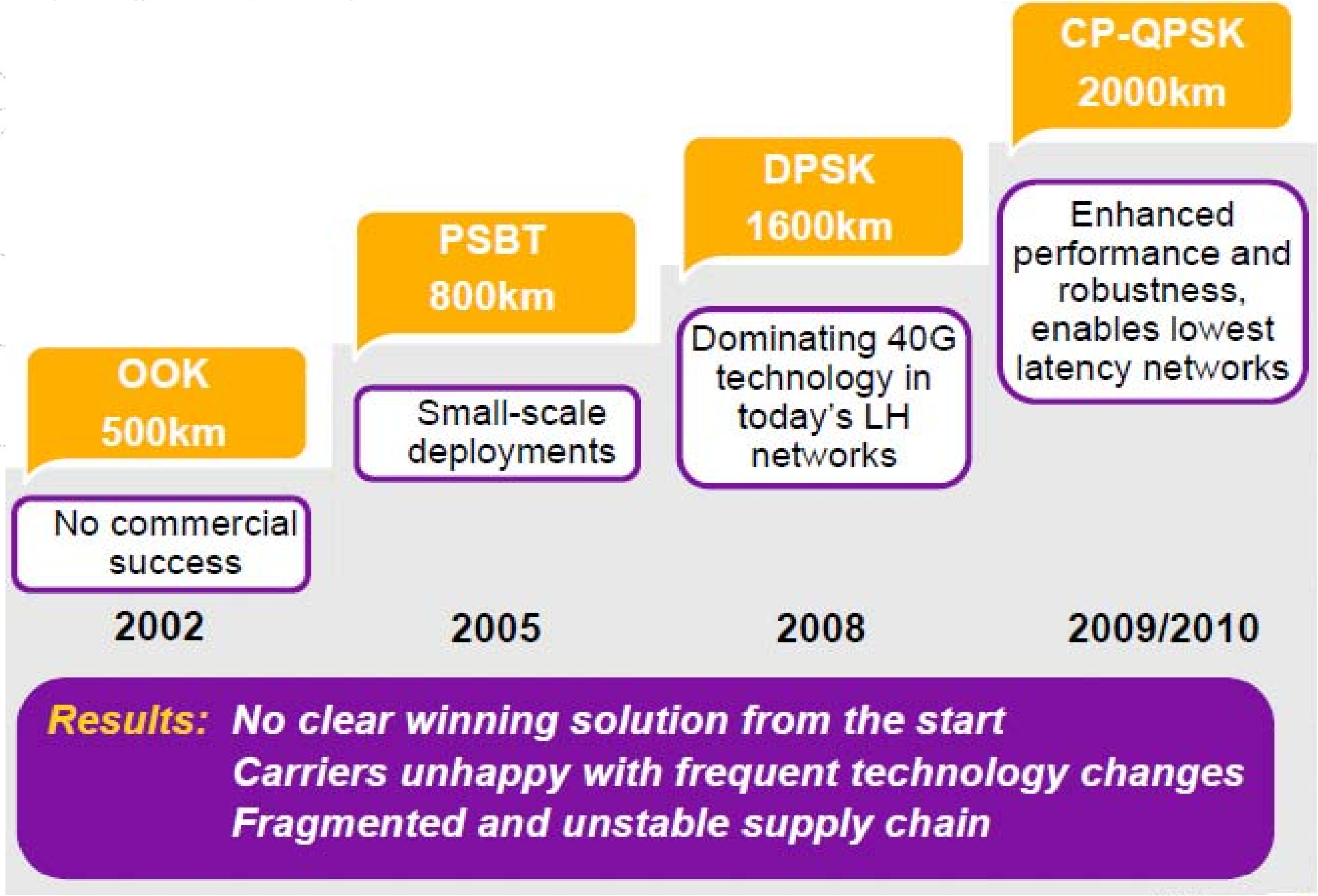
- **Four main market drivers of introducing 40G into long haul systems:**
  - Bandwidth growth
  - Reduction of Transmission Costs
  - Need to Relieve High-Capacity Bottlenecks
  - Support for the New Generation of IP Backbone Routers
- **Technical Issues for 40G DWDM**
  - OSNR Sensitivity
  - Chromatic Dispersion
  - Polarization Mode Dispersion
- **Forward Error Correction (FEC), Alternative Modulation Formats and Dispersion Compensation Techniques solved these issues, enabling commercial deployment of 40G technology**

BUT: 50% of the world internet traffic already runs on 40G servers (availability of components).

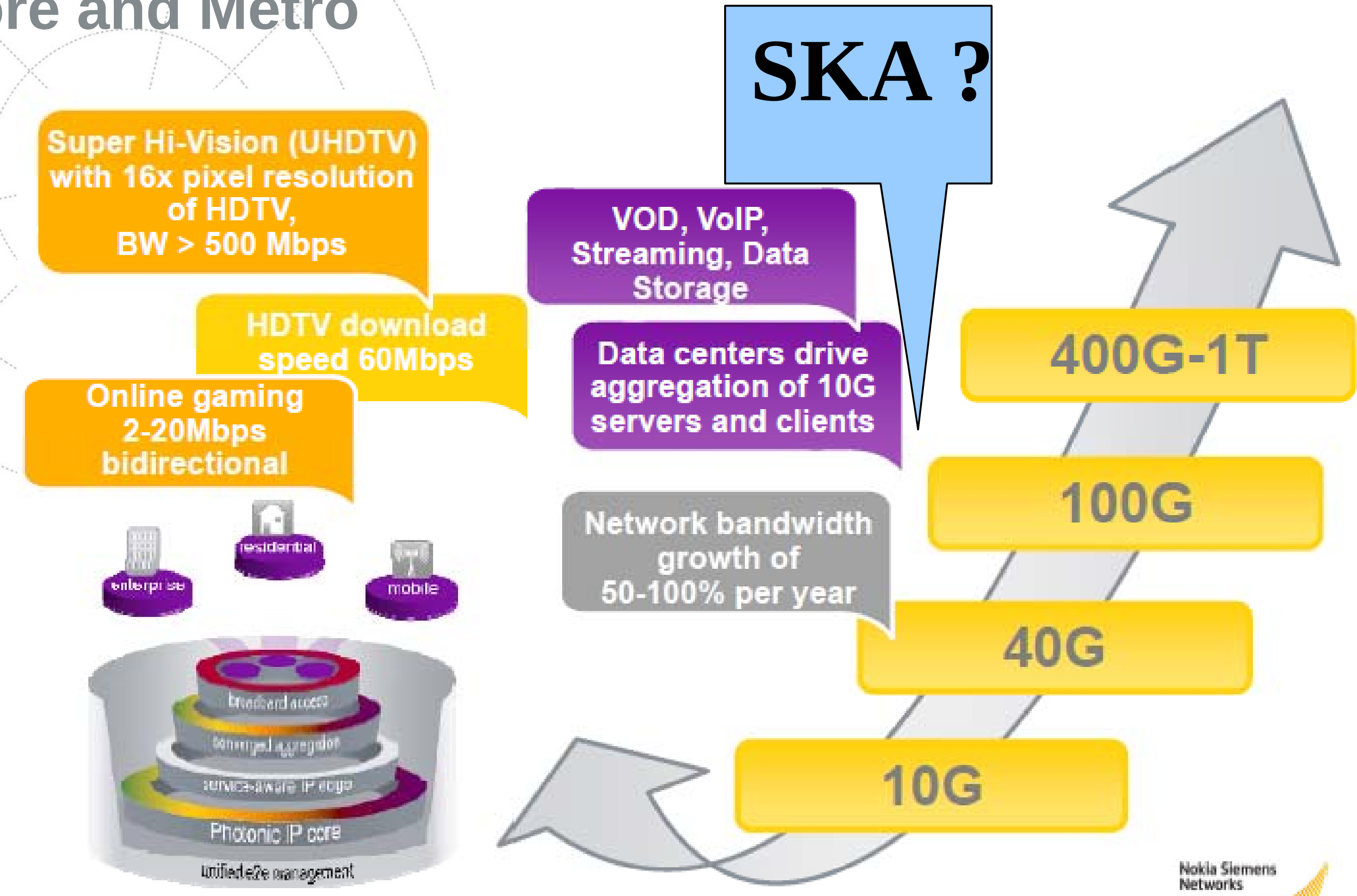
Caveats: 40G - Why Did It Take 10 Years for 40G To Take Off?

- Courtesy of NSN

The Four Technology Steps in 40G

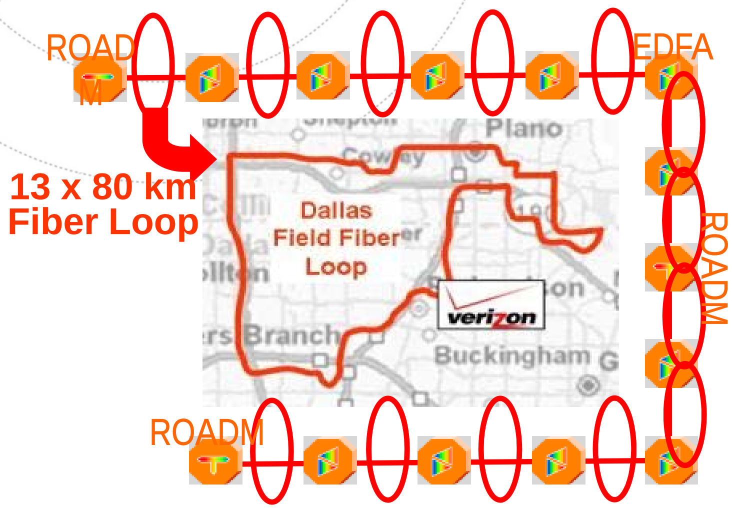


Increasing Network Traffic… Driver for 40G/100G in Core and Metro

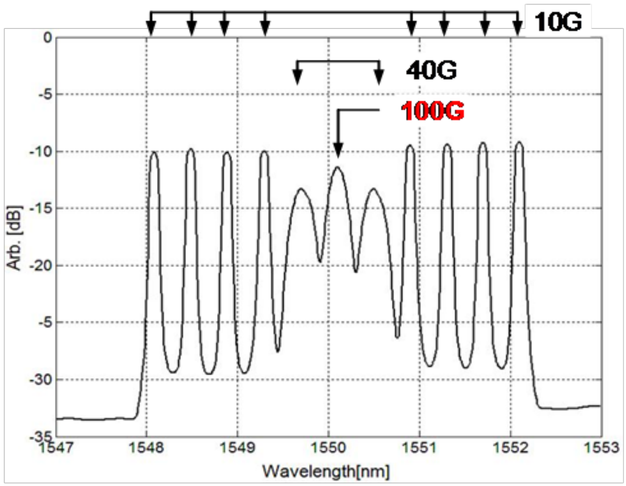


Convergence: 2008 - Field Trial mixed 100G/40G/10G over 1040 km ; NSN and Verizon

- **Experimental setup**:
  - 100G mixed with 40G and 10G over field deployed fiber, record distance 1040 Km.
  - 100G using 50GHz compatible **CP-QPSK**, 40G using DPSK, 10G using NRZ.
  - Standard chromatic dispersion map & PMD tolerance >23 ps mean DGD
- **Courtesy of NSN**



Spectra of 10G/40G/100G channels



World record reach of 1040 km. Mixed transmission of 100G/40G/10G on 50GHz equally spaced grid.
Addressing also green power solutions

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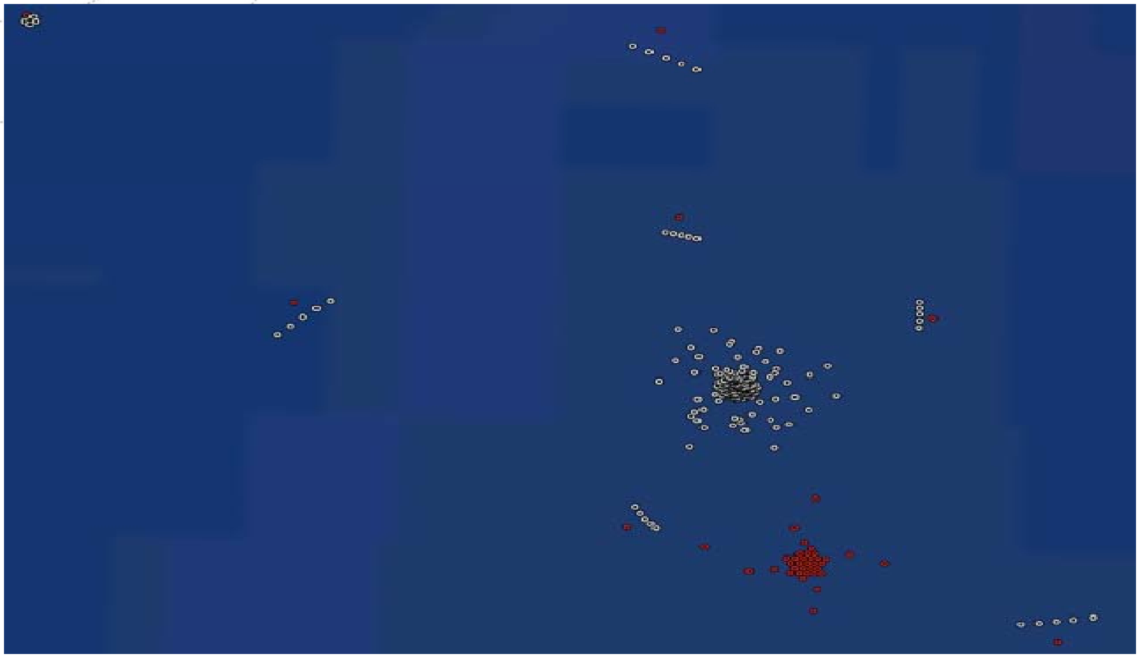
First pass on full SKA network configuration - Phase 1

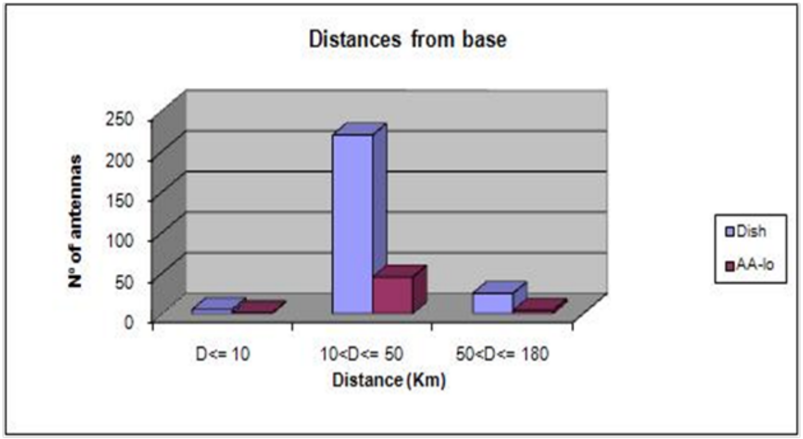
- Analysis of network behaviour and configuration dependence.
- Receptor is one way transmission
- M&C data is estimated at an additional 10Gbps bi-directional transmission/ receptor
- SKA1design must be SKA 2 compliant.



SKA Phase 1 Scenarios

- Several designs and measurements were made which included simulations for different distances, bit-rates and types of antennas.

- Here are shown the distances between the antenna base (antenna with ID = 0) and the others (dishes and AA-lo).



Distance (Km)	Nr of antennas	Nr of 10Gbps channels
D<=10	Dish=5; AA-lo=1	Dish=3 AA-lo=122
10<D<=50	Dish=220; AA-lo=45	
50<D<=180	Dish=25; AA-lo=4	

SKA Phase 1 Simulations

- Two different transmission Modulations were analyzed:
  - NRZ modulation, used and sufficient for short hauls (and low-debits generically). It is usually the cheaper as it has a widespread use.
  - CP-QPSK modulation, pointed by the industry as the next standard for long haul and high debits, provides a necessary upgrade path during the SKA lifetime.

- 10Gbps and 40Gbps simulation scenarios for Dishes
  - For 10km, a single SMF fiber was used along with NRZ modulation.
  - For 50km a DCF fiber was added in front of the SMF fiber for dispersion compensation.
  - For 100km and 180km link simulation, DCF fibers were used to compensate for dispersion, and the links were divided in two and three spans respectively in order to amplify the signal along them.

SKA Phase 1 - Simulations

- 10Gbps and 40Gbps simulation scenarios for AA-los and PAFs
  - Transmission required SMF and DCF fiber for dispersion compensation, given a 32 channel 40G transmission.

    Also here, depending on the distances of the links more than one span was used in order to reach desired results.
  - For PAFs, a 48 channel 40G transmission system was simulated, for 10km and 100km.

    The scenarios were similar to the ones tested for the AA-lo.
- NRZ modulation format + C-Band limit the number of channels to 40 with a channel spacing of 100G. Need for alternative modulation formats and coherent detection.

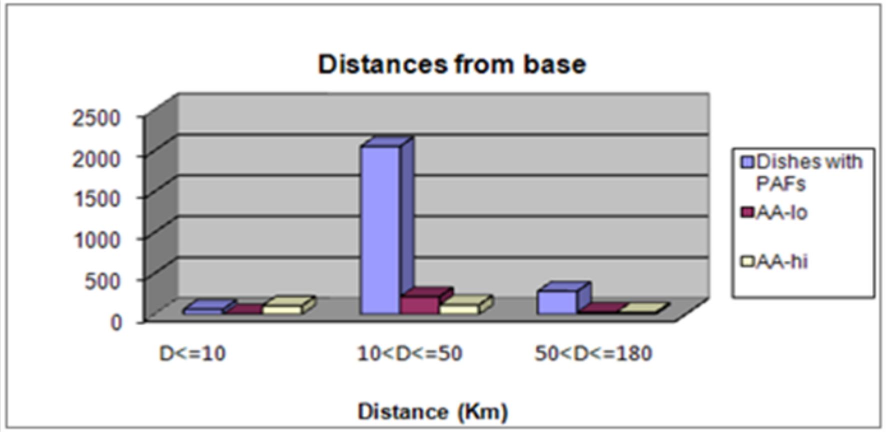
SKA Phase 1 – Simulations

- With this in mind, AA-lo scenario was simulated one more time, but employing DQPSK modulation format.
- With a suitable aggregation, it presents a very good result for the 32 channel system, and allows upgradability when aggregating more channels and higher bit-rates.

- In resume, the designs and measurements undertaken so far employed SMF fiber as well as DCF fiber for dispersion compensation.
- NRZ was the modulation format used, although for higher bit-rates and longer distances advanced modulation formats have to be applied.
- For this, the system must have upgrade capabilities.

SKA Phase 2

- To realize the full SKA, SKA1 will be extended to SKA2 in many terms.
- One of the major differences from phase 1 is the increase in the number of antennas.



Distance (Km)	Nr of antennas	Nr of 10Gbps channels
D<=10	Dish=62; AA-lo=6; AA-hi=107	Dish=186 AA-lo=3344 AA-hi=1860
10<D<=50	Dish=2054; AA-lo=218; AA-hi=117	
50<D<=180	Dish=284; AA-lo=26; AA-hi=26	

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SKA Phase 2

- Considering the addition of the 40G and the 100G scenarios, it implies an infrastructure development from the actual 10G scenarios.

- Scaling the system to higher bit-rates can only be successful if:
  - The 40G and 100G transmission format is compatible with already deployed transmission links.
  - It ensures compatibility with existing network topologies.

- From the previous points it can be seen that it is possible to upgrade for the next phase. Since 40G and 100G are in transition for market availability within the next years, Industry is planning equipment to be compliant with these major transmission rates.

Conclusions I

- **Nonfunctional requirements:**
  - Implementation dependent
  - Gives good knowledge of the SKA needs.
  - Achieved a good mapping of available options
  - Released for comments.

- Market mature and economically viable for 40G standard.

- Positive forecast for 40G/100G within SKA timeframes (possibility of SKA / AAVP field trials with exclusive 100G equipment - > at the forefront of ICT high-performance testing of Networks)

- Cause for cautious optimism (albeit many variables and scenarios still to be controlled/ analyzed)

Conclusions II

- Analysis will take new technology and pricing forecasts
- Weighting custom made needs vs industry providers capabilities.
- Industry is moving towards Coherent systems for long hauls.
- Good examples for mixed standard networks; easily upgradable and scalable.
- Triggered interest of major word leading industry (ex: SPDO NDA with Nokia Siemens networks)
- SKA phase 1 simulations and costing in the horizon.

Conclusions III

- This concept described the building blocks and related equipment in the digital data backhaul networks for Signal Transport and Networks (STAN), based on current and forecasted COTS technologies.

- Here we can divide the system on a fiber choice and equipment.

- The choice of fiber may impact upgradability scenarios, so we chose fibers whose type and quality can accommodate the SKA specifications and the expected upgrades in equipment performance during the SKA expansions phases and lifetime, according to a wide expert advice.

Conclusions III

- More specifically, and a critical aspect to the SKA stand, we analyzed the core problem as a function of a transmission capability as a result of the transmission technology roadmaps worldwide and current solutions.

- To source the information on the available technology and forecast the next 15 years of evolution, dedicated workshop were organized to stimulate discussion and know-how acquisition with some of the main companies like Erickson, Cisco and Nokia Siemens.

Thank You

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