The Versatile Link Common Project Phase II Addendum

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1 Introduction

The versatile link project officially started on 1 Apr 2008. It is subdivided in three phases:

- Phase 1: proof of concept
- Phase 2: feasibility demonstration
- Phase 3: pre-production readiness

Each phase lasts 18 months. This Addendum redefines the details of phase 2, due to run from 1st Oct 2009 to 31st March 2011.

1.1 Project and Associate Partners

The versatile link project partners are each responsible for a workpackage, as listed in Table 1 below. Project partners may collaborate with associate partners to work on specific, well defined tasks (see the workpackage description for more details).
Workpackages WP 1.2 and 1.3 have not yet been assigned. They will be launched once more experience will have been gained with the simpler system workpackage 1.1 and with the component workpackages 2.1 to 2.3.

Workpackage	*Description*	*Project Partner*	*Contact Person*
Proj. mgmt	Presides project steering board	CERN	Francois Vasey
WP 1.1	P2P architecture	Southern Methodist University, USA	Annie Xiang
WP 1.2 and 1.3	PON and other architectures	*open*	
WP 2.1	Front-end components	CERN, Switzerland	Jan Troska
WP 2.2	Back-end components	Fermilab, USA	Alan Prosser
WP 2.3	Passive components	University of Oxford, United Kingdom	Todd Huffman

Table 1 Project Partners

1.2 Deliverables

Phase 2: Feasibility study

- Detailed specifications for components and systems based on phase 1 recommendations and interaction with users
- System and architecture demonstrators with validated components
- Components and Variants shortlist
- Evaluation of production costs versus volume
- Complete set of irradiation test results for front-end and passive components
- Front-end Transceiver package definition and industrial prototype fabrication integrating GBT ASICs and validated optoelectronics

2 Detailed Workpackage description

2.1 WP 1.1 Point-to-Point architecture

Project partner: Southern Methodist University (Physics Department),
Work Package Coordinator: Jingbo Ye, SMU
Associate patner: Institute of Physics, Academia Sinica, Taiwan (Suen Hou and P.K. Teng)

2.1.1 Phase 2 (Feasibility Study)

In this second project phase, we plan to finalize system level specifications, demonstrate system prototypes and establish operations margins in close collaboration with other work packages. In addition, we will provide evaluation kits with a characterization guide for interested users.

Deliverables

1. System test procedures and benchmarks. A check list will be contrived based on industrial standards and modified according to phase I test experience.
2. System level specifications. Detailed specifications will be finalized, in particular a suitable mask will be identified and suitable limits for BER, availability and reliability will be defined.
3. Margins definition. System margins will be explored using models and real life tests under diverse environmental conditions (EMI, temperature, radiation, magnetic field, etc…) Test results will be used to incorporate realistic margins into system power and jitter budgets.
4. Prototypes. Prototype systems will be assembled based on components supplied by other work packages and resulting in single or multi-channel links. The characterization of these prototypes will allow validating the specifications and margins. Experimental results will be fully documented.
5. Compatibility with higher level system. The Versatile Link system performance will be reviewed to ensure that it meets the requirements of upstream and downstream elements of the chain.
6. Evaluation kits. Evaluation kits will be released to interested users based on qualified components from other work packages. Carrier boards, evaluation board hardware, firmware and software will be made available for test driving the versatile link evaluation kit.

Resources

Phase 2 deliverables aim to demonstrate a link system whose specifications derive from industrial standards and meet SLHC application requirements. During this phase, we shall work closely with teams of the other WPs as well as potential users. We anticipate a work load of one FTE for the above listed tasks.

2.2 WP 1.2 and 1.3 PON and other architectures

Will be activated once more experience will have been gained with WP 1.1, WP 2.2 and WP 2.3.

2.3 WP 2.1 Front-End components

Project partner: CERN
Work Package Coordinator: Jan Troska, CERN

2.3.1 Phase 2 (Feasibility Study)

In the second project phase, the following objectives are maintained:

- Full specifications for both the overall VTRx and its sub-components, along with a list of variants that will be produced.
- A full set of radiation test results for the sub-components covering a range of radiation sources to be confident that we have properly simulated the SLHC radiation environment.
- VTRx packaging design and industrial prototype fabrication. The VTRx prototype should include radiation-hard ASICs from the GBT project as well as those devices identified by the radiation testing to be the most radiation resistant.

Specifications

We will produce a full set of engineering specifications covering electrical, optical and environmental aspects for the VTRx. These specifications will be discussed firstly within the Versatile Link steering group and then made available for users to comment upon. After the first discussions within the steering group we will produce the detailed component specifications for the components of the VTRx (TOSA, ROSA, TIA, Laser Driver, VTRx printed circuit board and VTRx mechanical housing). All specifications will be iterated based upon comments received from manufacturers, steering group members and users in order to obtain a set of specifications that will lead to a cost-efficient and reliable final VTRx.

Radiation testing

Radiation testing in phase II will expose the most promising candidates identified from the Phase I tests to as wide as possible a range of sources in order to be confident that the final SLHC environment is correctly simulated by our tests. This is important because NIEL scaling for the complex III-V semiconductor compounds is not well established, something that we will also investigate in this phase.

We will carry out testing at a gamma source to verify that ionizing radiation does not adversely affect the packaging of the components in the first instance and finally the overall packaging of the VTRx. Gamma testing will also verify our expectation that ionizing radiation does not greatly affect the functional performance of optical transmitters and receivers. There will be one or two gamma tests in phase II to address these issues.

We will carry out one or two irradiations at the Louvain-la-Neuve cyclotron neutron beam facility to confirm the results obtained in 2009 and evaluate the feasibility of carrying out lower fluence testing for production qualification. The test setup will be improved to include online thermal measurements to be able to distinguish thermal from radiation effects. A further improvement will be that we will aim to add an online measurement that can track changes in the dynamic performance of the lasers during irradiation.

We aim to carry out one irradiation at a pion source to cross-check the scaling factors needed to correctly simulate the SLHC environment. This test will likely not reach the final SLHC fluence due to limitations of the available sources. Nevertheless, sufficient data to compare the degradation rates between the above neutron source and a 300 MeV pion beam will be taken to extract the scaling factors. This test will likely include a reduced set of DUTs due to the limited available beam area and flux.

We will carry out one or two SEU tests in Phase II in order to confirm the burst error statistics gathered in our previous tests and to widen the range of bit-rates over which we have SEU data. We will use a reduced number of DUTs by selecting the most promising devices from our first test. In addition, we will include the GBTIA in our tests to assess its performance and provide feedback to the chip designers for potential future SEU-hardening of the design.

Packaging

The packaging work will concentrate of the customization of the VTRx housing and measurement of the impact of this on the VTRx performance – both in terms of functional and environmental (EMI/C and temperature) performance.

We will pursue two parallel paths for package customization, one working with an industrial partner to modify an existing design, and the other working with in-house expertise to design several mechanical variants in order to assess their production feasibility. The same parallelism applies to the design of the printed circuit board inside the VTRx. The objective is to have prototypes within twelve months in order to have a final design concept prototyped for the end of Phase II.

Testing of the Electromagnetic emissions of the modified packages will be established so that we can add this as a criterion for comparison of different designs. We will also study the thermal management of the module in order to check the relative merits of different designs and provide advice to users for system implementation.

Resources

Resources at the level of 4 FTEs are expected to be available to carry out this work plan.

2.4 WP 2.2 Back-End components

Project partner:Fermilab
Work Package Coordinator: Alan Prosser

2.4.1 Phase 2 (Feasibility Study)

The activities in WP 2.2 include the evaluation of commercially available optical communication components such as:

1. Point to point (P2P) transceivers
2. Array receivers and transmitters
3. High power optical transmitters
4. Passive Optical Network (PON) transceivers

The evaluation of P2P transceivers (SFP+ devices) was included in Phase 1 activities and will continue in Phase 2. Devices have been obtained which operate at 850 nm for transmission distances on the order of a few hundred meters. For compatibility with installed fiber plant at CERN, we also will investigate 1310 nm devices (with single mode fibers).

High power optical transmitters, array transmitters and receivers as well as PON transceivers are to be investigated to determine their suitability in various network topologies. The use of these components offers advantages which will be attractive as more detector channels are provisioned in the proposed upgrades. Fermilab had begun the investigation of possible components but testing has not yet begun (as of the completion of Phase 1 of the project). We propose to obtain and evaluate representative samples of commercially available devices which are typically

used to implement different network topologies. The performance characteristics which are measured may be useful in defining the specific topology which will work best for the SLHC data networks.

Collaborative Synergies

The testing that is to be performed will make use of the FPGA based BER testing capabilities developed by WP1.1. There will be a need to work closely with these colleagues to fully understand these test benches and methods. It will also be beneficial to provide frequent feedback on test results and lessons learned from our activities to the rest of the collaboration.

Activity Summary (SFP+ 10 Gbps Transceivers)

1. The detailed test plan begun during Phase 1 must be updated to reflect new equipment and modified testing techniques for P2P devices. This test plan must also be updated to reflect the approach to testing parallel optics components.
2. The WP2.2 test station at Fermilab will be enhanced with the arrival of a single mode variable optical attenuator (already on order) from JDSU. This equipment will enable the measurement of receiver sensitivity on single mode devices by allowing controlled levels of attenuation to be introduced into the optical signal path.
3. Perform additional testing of SFP+ components to simulate stresses that might be experienced in operation (for example, tests at higher temperatures or EM noise to simulate operation in equipment racks).
4. Complete the testing of the SFP+ components and designate reference components (for 850 nm and 1310 nm devices) for the other members of the Versatile Links team. The documentation of test results will be updated to include presentation using spider plot techniques.
5. Obtain a significant quantity of each type of component to ensure that test results are representative, and be able to distribute samples to other work packages.
6. Evaluate industrial quality control procedures. Consult component vendors for guidance on quality control procedures for production level engineering. Provide budgetary cost estimates versus volume for these components.
7. Write up detailed specifications for back end SFP+ transceivers.

Activity Summary (Parallel Optics)

1. A test board for use as a demonstrator for parallel optics components from a commercial vendor will be designed. This board is intended for use with the FPGA based test hardware that Fermilab has already procured.
2. Identify and procure additional parallel optics components for testing (for example, SNAP 12 components).
3. Perform measurements on a per channel basis of the parallel optics components in this demonstrator test. The measurements will be the same as those used to characterize individual transmitter and receiver performance in SFP+ devices (eye based measurements, jitter characterization). Also, perform tests to examine cross coupling effects in this system.
4. Recommend a collection of parallel optics reference components. Obtain a significant quantity of each type of component to ensure that test results are representative, and be able to distribute samples to other work packages.
5. Evaluate industrial quality control procedures. Consult component vendors for guidance on quality control procedures for production level engineering. Provide budgetary cost estimates versus volume for these components.
6. Write up detailed specifications for back end parallel optics component.

Activity Summary (High Power Devices and Passive Optical Networking Components)

1. Identify potential components for testing. Identify any additional test equipment or techniques required by the addition of these new devices to the suite of components to be tested.
2. Procure a sample of relevant devices. Develop test methods and setups.
3. Evaluate performance in lab measurements.
4. Recommend a collection of reference components. Obtain a significant quantity of each type of component to ensure that test results are representative, and be able to distribute samples to other work packages.
5. Evaluate industrial quality control procedures. Consult component vendors for guidance on quality control procedures for production level engineering. Provide budgetary cost estimates versus volume for these components.

1. Write up detailed specifications for back end PON components.

Deliverables

- Detailed specifications for transceivers and parallel optics modules
- Short list of components suppliers (transceivers, parallel optics modules and high power transmitters), with a documented complete set of experimental results
- Portfolio of components available to other workpackages
- List of recommended component types for evaluations by external users
- Budgetary cost estimates vs volume.

Resources

Calendar Year	2009	2010	2010	2011
Quarters[(a)]	4	1, 2	3, 4	1
Project Phase	2	2	2	2
FTE-Engineer	0.75	0.75	0.75	0.75
FTE-Technician	0.75	0.75	0.75	0.75

Quarter 1 includes January, February, and March of the indicated calendar year.
Quarter 2 includes April, May, and June of the indicated calendar year.
Quarter 3 includes July, August, and September of the indicated calendar year.
Quarter 4 includes October, November, and December of the indicated calendar year.

2.5 WP 2.3 Passive components

Project partner: University of Oxford,
Work Package Coordinator: Todd Huffman
Associate patner: Institute of Physics, Academia Sinica, Taiwan

2.5.1 Phase 2 (Feasibility)

We propose to develop a simple blow-off CO_2 cooling system with flexible delivery lines to allow evaporative cooling of the fibres in the radiation vessel at the Brigitte facility at SCK-CEN. When we have verified the operation of this system, we will perform the cold fibre irradiation measurements. This will be done for both the two candidate multimode fibres (Infinicor SX+ and Draka RHP-1) as well as a candidate single mode fibre (SMF-28), up to SLHC-level total doses.

We will pursue the unofficial market survey of PLCs and obtain new samples for evaluation before and after irradiation. We will determine the temperature sensitivity of PLCs. Warm radiation performance of PLC's will be characterized in Phase II of the project with cold radiation tests performed only if the system design places them inside the cold volume of the detectors.

The long-term reliability of Optical fibres is extensively studied by fibre companies using data from pull testing. They however do not normally perform their studies on irradiated fibres. We have a bid in for a project studentship and money for a pull test machine. If successful we will attempt a full reliability analysis of our candidate optical fibres both before and after radiation in close collaboration with our industrial partners. A re-assessment of this part of the programme will be needed if our funding situation is difficult.

We will need to begin to identify cabling solutions. Cabling solutions must identify rugged jacketing, ribbon cables or equivalent, and final connector solutions for single fibres (LC connectors) and ribbon fibres (MPO connectors) suitable for the environment (temperature, magnetic field and radiation field). We will develop jigs to allow for automatic multiple mate-demate cycles and measurements. If significant degradation with radiation is observed, we will study the radiation effects on bare ferules or MT connectors.

We will perform irradiation studies of fibre cables and fibres in proton beam(s). We have identified the MC40 cyclotron at Birmingham University, as a suitable source for these tests. It has a beam energy of ~ 30 MeV and a sufficient intensity to achieve SLHC fluences in one day. We will use a scanning box being constructed by our ATLAS colleagues for irradiation of silicon detectors, in order to achieve a uniform irradiation over an area of 10cm * 10 cm. We will perform before and after irradiation pull tests of our candidate fibres. We plan to get before and after radiation measurements of the mechanical strength of the fibre cables to be performed by a suitable fibre company. We aim to perform similar studies with low energy neutrons from a reactor at SCK and if necessary with high energy hadrons from the SPS.

We intend that Optical muliplexers will only be investigated when a suitable system architecture has been developed and can therefore be delayed to Phase III of the project.

At the end of phase II, detailed specifications will have been drafted for fibre, cables, connectors and splitters. A shortlist of companies capable of supplying products compatible with these specifications will have been

established. A set of documented experimental results will attest compliance and samples will have been made available to other workpackages to perform compatibility and system-level tests.

Deliverables

- Fully Qualified Optical fibre candidates in MM and SM types from at least two vendors for the SLHC environment.
- Paper of detailed cold fibre radiation test results.
- Fully qualified splitter candidates in MM and SM types.
- Documentation of splitter functionality and radiation tests
- Suitable single and ribbon connectors identified.
- Documentation of single and ribbon connectors tests
- Cabling options identified and documented.
- Detailed specifications for fibre, cables, connectors and splitters
- Budgetary estimates for fibre, cables, connectors and splitters
- Define and get approval of phase three of the Passive Component work package programme.