# Demonstration of Novel Silicon Optical Switching on Digital Radio over Fibre Link for Next-Generation Fronthaul

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**Abstract:** We for the first time propose a silicon photonic switching architecture for digital radio-over-fibre fronthaul links. An RF input power dynamic range of 55dB is demonstrated for 8% EVM with system receiver sensitivity of -23.9dBm. © 2021 The Author(s)

## 1. Introduction

With the fast expansion of 5G networks, there is an increasing demand for a new fronthaul architecture to lower capital and operational expenditures (CAPEX and OPEX) of last-mile wireless coverage. The fronthaul link, connecting centralised baseband units (BBUs) and remote radio units (RRUs), delivers digitised RF services as defined in the Common Public Radio Interface (CPRI) standard over fibre-based infrastructure. The current solution sends all aggregated CPRI data from the BBU pool to the RRUs without any traffic shaping [1]. Newly defined radio over Ethernet (RoE) protocol enables an evolved architecture allowing smart traffic manipulation and coordinated networking through packet-based transmission and switching [2]. This switched fronthaul can intelligently distribute bandwidth, no. of antennas and services to the RRUs using smart control mechanism. However, the excessive Ethernet and CPRI overheads, the latency introduced by packet processing and optoelectrical conversions limit the overall feasibility for practical rollout targeting at wideband services especially when millimetre wave (mmW) and massive multiple input multiple out (MIMO) techniques are used. Silicon photonics (SiP) has been demonstrated as a key platform for all-optical interconnects [3], and can be applied to increase the capability and converge for future-proof 5G transport networks [4]. In this paper, we propose an all-optical digital fronthaul architecture with micro-ring resonator (MRR) based silicon switch fabric and experimentally demonstrate the transmission of several digital RF services over an optically switched link for the first time. The RF performance is measured to validate the feasibility of the system.

## 2. Envisaged Optical Switching Architecture for D-RoF Fronthaul Links

The proposed optical switching architecture enables dynamic data transfer from BBU to RRUs in the fronthaul link, as shown in Fig 1a. The architecture can support data transport between different nodes with high flexibility and scalability. A SiP switch-and-select optical switch is deployed for space-and-wavelength selective routing, which has been used to drive analogue radio-over-fibre services [5]. We hereinafter experimentally demonstrate provisioning digital radio-over-fibre service for the fronthaul links with SiP MRR optical switch fabric.

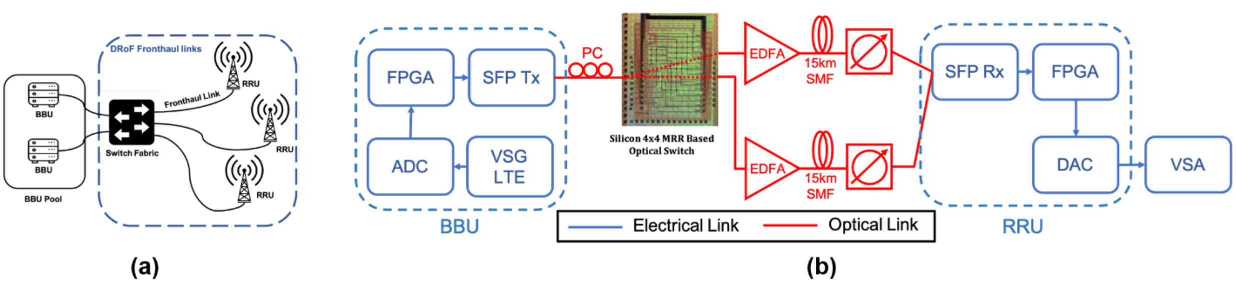


Fig 1(a) Silicon switch fabric deployment among fronthaul links. (b) Schematic experimental block diagram with a 4x4 silicon MRR-based switch layout.

## 3. Experiment Setup and Results

The experimental setup is illustrated by Fig 1b. A 20MHz bandwidth 4G LTE signal with 64 quadrature amplitude modulation (QAM) at a 37.5MHz intermediate frequency (IF) is generated from a vector signal generator (VSG). A digital-to-analogue converter (DAC) and an analogue-to-digital converter (ADC) are applied at the transmitter and receive end of the optical link, respectively. Data compression and packetization of the digitised data are processed on an FPGA, which also decompresses and depacketizes the received electrical signal before passing the signal to the DAC [6,7]. The transmitted data rate per service is 1/3 than that of CPRI. A HUAWEI small-form pluggable plus (SFP+) optical transceiver module conveys the information over optical carrier at 1538.65nm.

The design of the switch chip used in this work applies the switch-and-select architecture, comprising two linear switching arrays connected by a passive central shuffle network as shown in Fig 2a. This device is similar to the one reported in [10], but with all elements fabricated in the silicon layer. The MRR elements are biased at ~2.8V to tune the rings on resonance at the transmission wavelength. 0.3dBm polarization controlled light from the SFP+ transceiver was routed from input port 2 to output port 1. The fibre-to-fibre loss is measured at 14dB, which is mainly attributed to the fibre coupling from/to the chip. An EDFA is thus used to compensate for the loss. The output is connected to a 15km single-mode fibre as a fronthaul link. A variable optical attenuator (VOA) is implemented to adjust the optical received power before the SFP+ receiver. At the RRU, IF signal is recovered back to electrical format and upconverted to an RF at 2.1GHz frequency. The RF and optical dynamic range is evaluated by a vector signal analyser (VSA) to measure the error vector magnitude (EVM) of the output RF signal versus different RF and optical input power running at 2/4/6/8 Gbps, the data rates of the replicated 4/8/12/16-channel LTE services respectively .

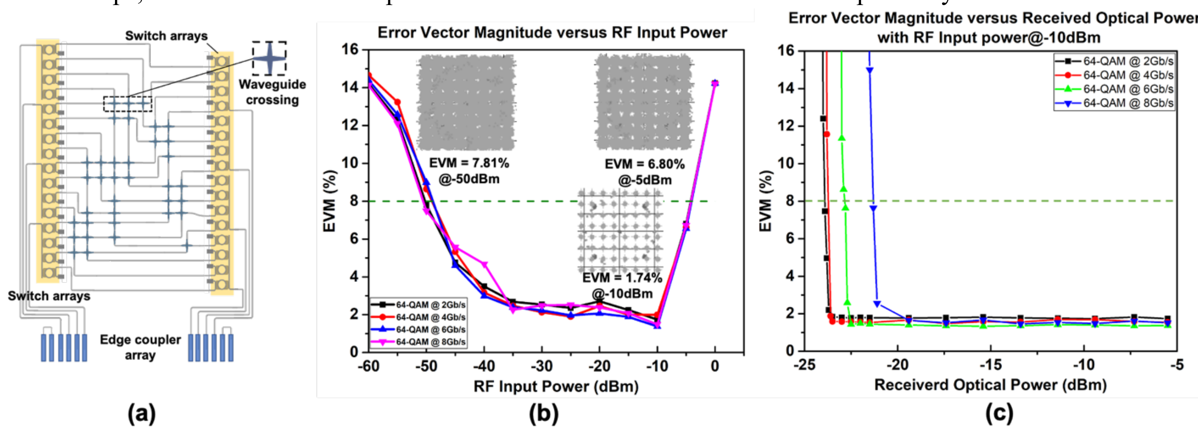


Fig 2. (a) Schematic of silicon 4x4 MRR ring based switch (Reprint from [9]). (b) EVM vs RF input power with the received constellation diagrams of 64-QAM with RF input power at -50dBm, -10dBm, -5dBm. (c) EVM vs received optical power at -10dBm RF input power.

Fig 2b shows the received constellation diagrams at RF input powers of -50, -10 and -5 dBm for a data rate of the D-RoF signal of 2Gbps, for the <8% EVM requirement specified by 3GPP for 64QAM [8], the RF input power dynamic range is over 55dB at the 4 different data rates, with the minimum EVM of 1.49% achieved at -10dBm RF input power. The optical dynamic range is measured by varying the VOA gain. As shown in Fig 2c, a rapid increase of EVM occurs at -23.9dBm, -23.6dBm, -22,7dBm, -21.3dBm for 2/4/6/8 Gbps data rates respectively. At 8Gbps, over 15dB optical link budget is available for additional optical processing and transmission.

## 4. Conclusion

In this paper, we describe a novel silicon switching architecture for D-RoF fronthaul. The experiment shows >55dB RF input power dynamic range at 8% EVM and >15dB optical link budget at 8Gbps, equivalent to 16 20 MHz LTE channels. This architecture provides a promising solution for next-generation fronthaul and offers efficient dynamic traffic management and coordinated networking through MRR-based optical switching. Future 5G testing is to be carried out upon availability of test and measurement equipment.

## 5. Reference

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