**A SOURCE-SYNCHRONOUS DESIGN FOR ON-CHIP SILICONE PHOTONIC INTERCONNECTS LEVERAGING MODE-DIVISION THE MULTIPLEXING**

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**ABSTRACT:**

A 3-mode 750 m Silicon photonics structure is used in an experimental demonstration of a source-synchronous connection employing modedivision multiplexing (MDM) for future usage in on-chip applications. Results for the simultaneous transmission of two data channels on two different modes, sampled by an optically forwarded clock delivered on a third distinct mode (bit error rate 1012 at 10 Gb/s), are reported. The mode assignment for the clock's performance is evaluated. The experiment demonstrates the significance of optimal clock location at wavelengths with increased modal crosstalk. For instance, at 1553 nm, the clock's jitter drops from 45 ps to 2.7 ps when it is encoded on a mode with high crosstalk (18.6 dB) to one with low crosstalk (28.6 dB), depending on the crosstalk level. The clock's jitter is 2.6 ps (about 27.8 dB crosstalk) at 1560 nm, where modal crosstalk is better, and 1.1 ps (about 34 dB crosstalk), without and with optimal clock location, respectively.

The optical link becomes operational across an optical bandwidth of 11 nm, allowing MDM-wavelength-division multiplexing topologies, with correct clock to mode assignment.

Integrated optics, mode-division multiplexing, optical interconnects, and source-synchronous connections are the terms used in the index.

**INTRODUCTION:**

Due to the integration density increasing with decreasing CMOS technology nodes, MOORE's Law brought about a period in 2014 in which eight trillion transistors were produced every second [1]. System on chip (SoC), system in package, and many-core architectures are now possibilities because to the rise in integration, functionality, and manufacturing advancements [2], [3]. The primary connectivity method used in integrated circuits has been electrical linkages.

However

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The shortcomings of copper cables are escalating as interconnect data rates rise. Attenuation that is frequency dependent can be troublesome, as seen by the 20 dB loss at 10 GHz across a 5 mm on-chip copper connector [4]. Intersymbol interference results from this, which may call for the use of high power equalisation procedures. Due to its compatibility with existing CMOS technologies and the numerous opportunities it opens up for low-cost on-chip applications, integrated silicon photonics (SiP) has grown in importance as a research area.

The solution to the high-speed and huge bandwidth needs for SoC applications is to use optical interconnects as the high-speed link within or between these self-contained processors [5], [6]. The authors of [7] investigated the frequency density issue for both electrical and optical I/O and came to the conclusion that optic connections using multiplexer methods, such as wavelength-division multiplexed (WDM), might outperform electrical connectivity at both the die at packaging level.

Synchronisation is crucial for sending data. Electrical connections frequently employ source synchronous links, which transmit a clock signal along with the data [8]. In order to minimise the requirement for power-hungry clock and data recovery systems on the receiver side, this is done. Due to the noise correlation between clock and data signals, source synchronous connections are advantageous for data transfer [9]. Because the gap between the clock jitter and the data jitter is reduced, the timing margin may be improved because the clock edge and data bit track one another. The similar synchronisation issue exists in optical interconnects and has to be overcome.

For optical networks employing WDM, the source-synchronous design has also been demonstrated in [10] and more recently in [11].

A number of lasers are needed when utilising WDM to boost interconnection capacity, which raises complexity, power consumption, and operational expenses. One laser is all that is needed for mode-division multiplexing (MDM), which has lately gained popularity in on-chip applications. Unlike WDM, MDM uses a single wavelength to transmit data about several electromagnetic confinements, or modes. Other MDM research either examined novel structures or tested the bit error rate (BER) for asynchronous data (clock retrieved at receiver) [12, 13].

Our earlier research in [14] and [15] demonstrated a new application of MDM to build a source-synchronous connection utilising a single optical channel, one clock mode, and one data mode. The connection can send numerous data channels and a clock signal to maintain synchronisation using different transmission techniques.

employing a single wavelength in the same waveguide. In Fig. 1, the suggested MDM architecture is depicted. The single-mode waveguides (SM WG), which are multiplexed into distinct modes (1 to N), are modulated by the transmit side (TX), together with the transmit clock on a different mode (Mode 1 in this picture). The optical signals are optically mode-demultiplexed onto SM WG on the receive side (RX), where they are then electrically recovered using the forwarded clock that has been deskewed (phase synchronised) and utilised in the latches.

The study given in this paper illustrates the operation of MDM source-synchronous networks under co-propagation of different data modes and clock signal. The findings emphasise how crucial it is to comprehend how the clock signal is susceptible to modal crosstalk (XT). The channel lengths taken into consideration in this work are for on-chip ( 2 cm) interconnect applications. A 3 dB optical bandwidth of 11 nm from 1553 to 1564 nm was found utilising continuous wave (CW) laser measurement to characterise modal crosstalk for the first time. Then, at 1560 and 1553 nm, respectively, the lowest (41.7 dB) and greatest (19.6 dB) crosstalk wavelengths were found. The first demonstration of its type, the experimental findings in this study demonstrate the viability of MDM by concurrently delivering two data channels at 10 Gb/s and a 10 GHz clock on a single wavelength. This experimental demonstration directly samples the data at the receiver using the forwarded clock. On both copropagating data channels, BERs below 10-12 are attained at the wavelengths corresponding to the lowest (1560 nm) and largest (1553 nm) modal crosstalk.

The effects of modal crosstalk on clock jitter are then examined using time domain analysis of the forwarded clock signals.

The best clock location resulted from finding the mode with the lowest crosstalk at the two wavelengths mentioned above. This reduced clock jitter and enabled reliable data transmission throughout the whole optical bandwidth.

The essay is set up as follows. The passive SiP structure employed in this study and the notion of MDM are both covered in Section II. Crosstalk, skew, and jitter are mentioned when the approach is shown in Section III. The collected experimental data are then presented and discussed in Section IV.Finally, part V brings this essay to a close.

**EXISTING SYSTEM:**

In order to prevent various types of attacks in data transmission, both symmetric-key and public-key approaches have been proposed in the literature. In [12], two different message authentication protocols were proposed. The first protocol, named TESLA, is based on Message Authentication Code (MAC), and the design utilizes a one-way key chain and timed release of keys by the sender. However, the TESLA protocol requires synchronization among devices, which is difficult to implement in a large scale network. The second protocol in [12], named EMSS, is based on cryptographic hash function and public-key technique, and can achieve the security property of non-repudiation.

In [13], an interleaved hop-by-hop authentication scheme was proposed to prevent the injected false data packet attack by attackers or compromised

nodes in the network. Their scheme is symmetric-key based, and the basic idea is that multiple sensor nodes have to endorse a message (or report) using MACs in order to achieve message authentication. A similar approach was also proposed in an

independent work by Ye et al. [14]. In [15], a polynomial based approach was proposed to achieve lightweight and compromise-resilient message authentication, where messages are authenticated and verified via evaluating polynomials. In [8], Li et al. proposed a ring signature [16] based solution to achieve message authentication. Their scheme utilizes a ring signature scheme derived from the modified ElGamal signature scheme [10], and can achieve better features and performance in several aspects compared with the previous solutions. However, as we will demonstrate later, the ring signature scheme proposed in [8] has a security flaw: it allows an attacker to arbitrarily form a ring and forge a valid ring signature from an existing one. Such an attack has been considered in the literature of ring signature (e.g., [17]) and in this work we introduce a technique similar to that of [17] to fix the flaw without introducing any computation or communication overhead.

There are also a number of research works on privacy preserving user authentication (and key agreement) protocols for IoT and wireless sensor networks (WSNs) in recent years (e.g., [18], [19], [20], [21], [22], [23], [24], [25], [26]). These works focus on remote user authentication, which is related but different from the privacy preserving hop-by-hop message authentication considered in this paper. Moreover, due to the concerns on the physical security of sensor nodes and IoT devices, the research on constructing lightweight and physically secure authentication protocols for IoT and wireless sensor networks has also become a popular topic in recent years. To ensure physical layer security, Physically Unclonable Functions (PUFs) and wireless channel characteristics (such as the Link Quality Indicator (LQI)) are popular choices to enable security even if a sensor node is captured by an adversary. Several novel lightweight authentication protocols with physical security for IoT and WSNs can be found in [27][28][29].

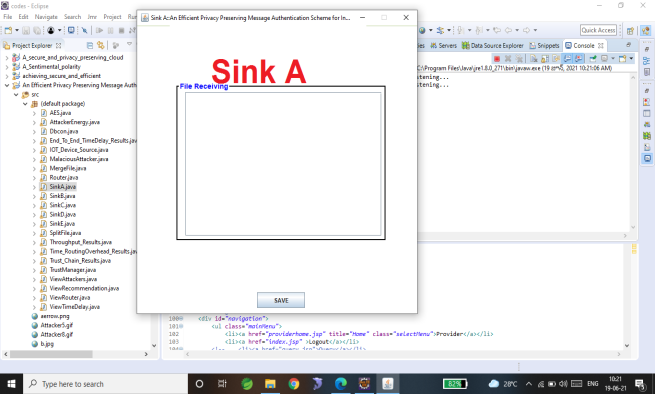
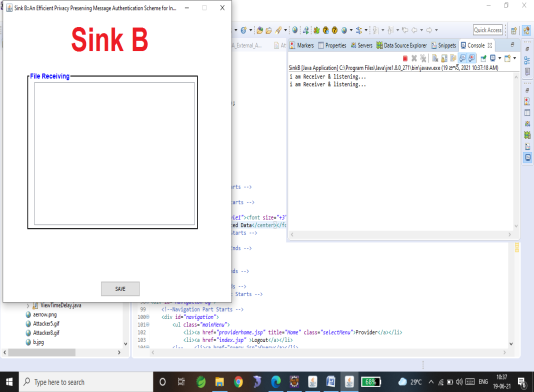
**PROPOSED SYSTEM:**

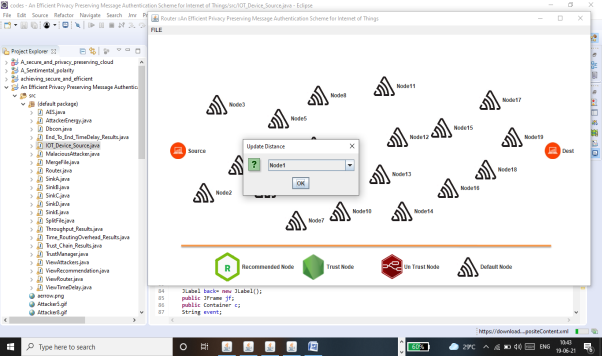
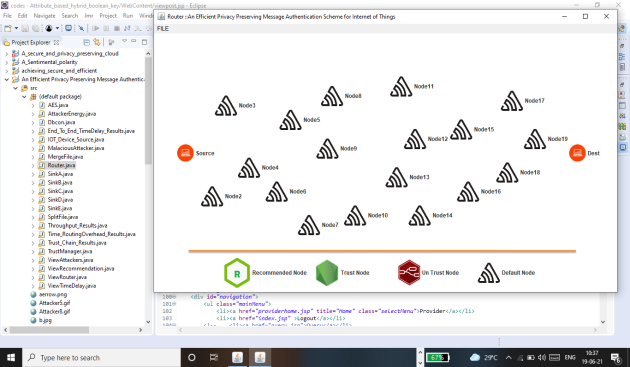
Moreover, considering the low computation power of the IoT devices, we also apply the offline/online paradigm in the design of our system. Efficiency is extremely important in practical IoT scenarios such as industrial automation, environmental

monitoring, smart grids, etc. In proposed scheme, a smart device can perform some expensive public-key operations offline (e.g., when it is idle), and only does the online computation when the message to be sent is ready. Interestingly, we find that by allowing both RSA and ElGamal type systems in our scheme, we are able to reduce the computation cost compared with the pure ElGamal scheme proposed in [8]. This may look counterintuitive since it is known that the ElGamal system (implemented using Elliptic Curve Cryptography, or ECC for short) is much faster than the RSA system. The reason of this counterintuitive fact is that in our hybrid scheme, for most of the RSA nodes, we only need to do RSA signature verification,

which is very fast since the RSA public exponent e can be very small. The proposed new SAMA scheme is compared with the previous scheme in terms of its execution time during signature generation and verification. We also implement our scheme in a laptop and in a Raspberry Pi to demonstrate its practicality.

**RESULT:**



CONCLUSION:

This study examined the integrity of the clock signals in an MDM-based on-chip interconnect architecture. Measurements reveal that the decision of which mode to transmit the sensitive clock signal is critical since different modes get crosstalk from various sources. Finding the mode with the least crosstalk at a particular wavelength allowed for the best clock-mode matching, which reduced clock jitter and enabled reliable data transmission over the whole optical bandw

Idth.

The experimental configuration used to get the results indicated that cumulative crosstalk below 21 dB on the clock channel resulted in a BER of 1012. If there was more crosstalk than this, the jitter increased exponentially, which made it difficult to receive data. As a result, one may use polarisation schemes utilising the TE and TM modes to boost the throughput in this suggested source-synchronous method, providing they satisfy the receiver's criteria for crosstalk and jitter.

Theoretically, rather than the skew disparities, the number of modes is constrained by the ensuing cumulative modal crosstalk. This is because most skew issues won't arise at the on-chip size we are aiming for ( 2 cm). One broadcast clock is all that is needed to synchronise the receiver and transmitter because the electronics at the reception manage deskew on a per-channel basis.

We think that the receiver's electronics' space, power, and total crosstalk requirements are the only factors limiting the number of data channels that can be transmitted to the receiver.

It is intriguing to apply the MDM approach across a wide band response because it expands the potential applications of the suggested technique as MDM may be used with various wavelengths (WDM). This may be expanded, for instance, to numerous source-synchronous connections where each WDM channel has a unique clock.

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