# Design and Execution of a Dynamic Subchannel Allocation and Modulation-Based Adaptive OFDM-Based Wireless Network-on-Chip Architecture

RAJESH DURGAM
Assistant Professor in ECE
rajeshdurgam2001@gmail.com
Malla Reddy College of Engineering

Dr.P.SUDHAKARA REDDY
Associate Professor in ECE
drpsr2022@gmail.com
Srikalahasteeswara institute of technology, Srikalahasti

**Abstract—** For many-core systems, Wireless Network-on-Chip (WNoC) is a new communication technology that offers low latency and high throughput via wireless connectivity. By splitting a wideband channel into several narrowband subchannels, orthogonal frequency division multiplexing (OFDM) enhances wireless communication. The present OFDM-based WNoC design uses bandwidth-based allocation and subchannel grouping to provide concurrent communication between the CPU, GPU, and memory subsystems. However, as communication traffic and wireless channel conditions change over time, fixed subchannel allocation could not make the most use of available channel resources. The adaptive OFDM-based WNoC architecture presented in this research makes use of adaptive modulation and dynamic subchannel allocation. Each subsystem's communication need is estimated by a traffic monitor, and available subchannels are assigned based on priority and demand by a dynamic allocator. An adaptive modulation controller chooses BPSK, QPSK, 16-QAM, or 64-QAM based on the channel state after a channel-quality estimator assesses signal-to-noise ratio (SNR) and bit-error-rate (BER) data. Data buffering, serial-to-parallel conversion, IFFT/FFT processing, cyclic-prefix insertion/removal, parallel-to-serial conversion, RF interface blocks, and OFDM transmitter and receiver are all included into the design. Xilinx Vivado functional simulation and synthesis can be used to assess the design, which is described in Verilog HDL. Performance is evaluated in terms of hardware resources, power consumption, latency, throughput, and subchannel utilisation. The suggested architecture seeks to enhance many-core systems' communication flexibility and resource utilisation.

**Keywords—** Orthogonal frequency division multiplexing (OFDM), adaptive modulation, dynamic subchannel allocation, many-core architecture, channel quality estimation, Verilog HDL, VLSI, and wireless network-on-a-chip (WNoC).

## I. INTRODUCTION

Many-core system-on-chip architectures integrate multiple processing elements, including CPU cores, GPU cores, accelerators, and memory subsystems, on a single silicon die. As the number of cores increases, communication between distant processing elements becomes a major design challenge. Conventional wired Network-on-Chip (NoC) architectures use routers and metal interconnects to transfer packets. Although wired NoCs are scalable and well understood, long multi-hop paths may introduce communication latency, routing contention, and energy overhead.

Wireless Network-on-Chip (WNoC) has been investigated as a complementary communication fabric for many-core systems. On-chip wireless links can provide broadcast or long-distance communication between wireless interfaces, potentially reducing the number of router hops for selected traffic patterns. WNoC architectures nevertheless face constraints such as limited wireless channels, antenna and transceiver area, channel interference, medium-access coordination, and time-varying communication demand [1]–[4].

OFDM is a multicarrier modulation technique in which a high-rate data stream is distributed across orthogonal subcarriers. The use of a cyclic prefix helps mitigate inter-symbol interference caused by multipath propagation, while frequency-domain equalization can reduce receiver complexity. In a WNoC environment, an OFDM link can be divided into subchannels that are assigned to different communication flows or groups of wireless interfaces.

A fixed resource assignment does not always match the instantaneous traffic demand of a many-core application. For example, a GPU-intensive workload may temporarily require more communication bandwidth than a lightly loaded memory interface. Similarly, the quality of a wireless link can vary due to interference, coupling, and changes in the on-chip propagation environment. Fixed modulation may therefore either waste capacity under good channel conditions or produce excessive errors under poor channel conditions.

This paper proposes an adaptive OFDM-based WNoC architecture that combines dynamic subchannel allocation with channel-quality-driven modulation selection. A traffic monitor measures the data demand from the CPU, GPU, and memory subsystems. A subchannel allocator assigns resources based on demand, availability, and priority. A channel-quality estimator provides SNR or BER information to a modulation controller, which selects BPSK, QPSK, 16-QAM, or 64-QAM. The resulting configuration is applied to the OFDM transmitter and coordinated with the receiver.

The main design objective is to create a hardware-oriented adaptive communication controller that can be described in Verilog HDL. The paper focuses on the digital control and baseband processing architecture. Actual RF front-end, antenna, and on-chip propagation behavior require technology-specific modeling and are outside the scope of a purely RTL-level functional model.

## II. RELATED WORK

**Dominic DiTomaso, Avinash Kodi, David W. Matolak, Savas Kaya, Soumyasanta Laha, and William Rayess, "A-WiNoC: Adaptive Wireless Network-on-Chip Architecture for Chip Multiprocessors."** The authors introduce A-WiNoC, an adaptable wireless communication fabric for chip multiprocessors. Its channel assignment adapts to bandwidth demand from different cores, with a background adaptation algorithm and token-sharing mechanism to improve wireless bandwidth utilization. This work is closely related to the dynamic resource-management layer in the proposed architecture [1].

**Suraj Jog, Zikun Liu, Antonio Franques, Vimuth Fernando, Sergi Abadal, Josep Torrellas, and Haitham Hassanieh, "One Protocol to Rule Them All: Wireless Network-on-Chip Using Deep Reinforcement Learning."** The authors present NeuMAC, a learning-based medium-access protocol that adapts to changing WNoC traffic patterns. The study shows the importance of responsive channel access and traffic-aware control in wireless many-core systems. The proposed design uses a simpler hardware-oriented traffic monitor and allocator rather than a deep-learning policy [2].

**Jianhua Li, Ning Wu, Yongliang Hu, and Xiaoqiang Zhang, "High-Performance Adaptive Hybrid Wireless NoC Architecture Based on Improved Congestion Measurement."** This work proposes adaptive wireless NoC operation using congestion measurement and dynamic bandwidth allocation. The architecture adjusts wireless resources according to traffic conditions, supporting the principle that channel capacity should be assigned based on current network demand [3].

**"Architecting a Priority-Based Dynamic Media Access Control Mechanism in Wireless Network-on-Chip."** This study investigates a priority-based dynamic MAC mechanism for WNoC. It uses waiting time and receiver congestion information to adjust access priorities and reduce delay under non-uniform traffic. Its resource arbitration concepts are relevant to the proposed traffic-aware subchannel allocation controller [4].

**Mitali Sinha, "A Utilization Aware Robust Channel Access Mechanism for Wireless NoCs."** The work proposes a comparator-based controller for flexible wireless channel allocation and uses power gating to reduce energy when wireless interfaces are not required. It demonstrates that utilization-aware control can reduce unnecessary channel-access overhead and energy consumption [5].

**Wonjong Rhee and John M. Cioffi, "Increase in Capacity of Multiuser OFDM System Using Dynamic Subchannel Allocation."** The authors formulate dynamic subchannel allocation for multiuser OFDM and present a low-complexity allocation algorithm. The study establishes that assigning subchannels according to channel and user conditions can improve system capacity compared with fixed allocation [6].

**Changwook Lee and Gi Joon Jeon, "An Efficient Adaptive Modulation Scheme for Wireless OFDM Systems."** This work combines subcarrier allocation and bit loading for adaptive OFDM. The allocation algorithm determines which subcarriers are assigned, while the bit-loading method selects the number of bits per subcarrier. These ideas provide a basis for selecting modulation order according to link quality [7].

**Sigen Ye, Rick S. Blum, and Leonard J. Cimini Jr., "Adaptive OFDM Systems with Imperfect Channel State Information."** The authors analyze adaptive OFDM when channel-state information is noisy or delayed. Their work highlights the effect of channel-estimation errors on modulation adaptation and spectral efficiency. The proposed channel-quality estimator must similarly account for estimation accuracy and update timing [8].

**Xiaozhou Huang, Hsiao-Chun Wu, and Y. Wu, "Novel Pilot-Free Adaptive Modulation for Wireless OFDM Systems."** The authors propose an adaptive modulation method that estimates SNR without relying on conventional pilot symbols. Their analysis demonstrates that modulation can be selected dynamically to satisfy a target BER while improving throughput under favorable channel conditions [9].

**Jia Tang and Xi Zhang, "Link-Adaptation-Enhanced Dynamic Channel Allocation for MIMO-OFDM Wireless Networks."** This work combines link adaptation and dynamic channel allocation for MIMO-OFDM networks. It jointly considers antenna selection, modulation level, and transmission power to improve throughput. The study supports combining subchannel allocation and modulation selection rather than treating them as independent decisions [10].

**Iordanis Koutsopoulos and Leandros Tassiulas, "Cross-Layer Adaptive Techniques for Throughput Enhancement in Wireless OFDM-Based Networks."** The authors investigate joint channel allocation, modulation-level selection, and power control across physical and access layers. Their work motivates coordinated control across traffic demand and physical-layer quality, which is reflected in the adaptive resource-management block of the proposed WNoC [11].

**Chang-Soon Choi, Yozo Shoji, and Hiroyo Ogawa, "Implementation of an OFDM Baseband with Adaptive Modulations to Grouped Subcarriers for Millimeter-Wave Wireless Indoor Networks."** This paper describes an OFDM baseband implementation that applies adaptive modulation to groups of subcarriers. Group-based modulation is relevant to a WNoC design because modulation and resource assignment can be controlled for subchannel groups rather than independently for every subcarrier [12].

**"Congestion-Aware Wireless Network-on-Chip for High-Speed Communication."** This study examines congestion-aware wireless NoC operation for communication between multiple cores. It discusses the need to adapt network resources as traffic conditions change. Its focus on congestion supports the use of traffic monitoring as an input to dynamic subchannel allocation [13].

## III. PROPOSED SYSTEM

The suggested system is a wireless Network-on-Chip transceiver that uses adaptive OFDM to link a many-core system's CPU, GPU, and memory subsystem. An OFDM transmitter, an adaptive resource-management controller, an on-chip wireless channel model, an OFDM receiver, and

a network interface make up the architecture. The resource-management controller sets the baseband datapath's modulation mode and subchannel allocation after monitoring the communication demand and channel quality data. The entire architecture and its main functional components are shown in the provided block diagram. The transmitter receives destination, priority, and traffic information from the network interface, which gathers data packets from the on-chip processing components. Every subsystem's pending data volume or request rate is measured by a traffic monitor. Counters, queue occupancy, or request-valid signals can be used to represent the traffic data. Instead of depending on a fixed assignment, the monitor updates the resource management on a regular basis to reflect changes in workload.

Active communication flows are allocated available OFDM subchannels via the dynamic subchannel allocator. Queue occupancy, requested bandwidth, flow priority, and the quantity of available subchannels can all be taken into account when making the allocation choice. Threshold comparisons and a priority encoder can be used in a straightforward hardware solution to allocate resources. Additionally, unless the design specifically permits spatial reuse or coordinated sharing, the allocator must prohibit two transmitters from using the same exclusive subchannel simultaneously. To prevent altering the mapping in the middle of a transmitted symbol block, allocation updates must be synchronised with OFDM frame boundaries. An SNR estimate or a BER feedback value is used by the channel-quality estimator to assess the wireless-link state. These values could be provided by a receiver-side estimator or a channel model in a hardware prototype. The modulation controller can get a concise channel-state indicator from the estimator, which can also categorise the link into quality ranges. Filtering or hysteresis should be used in a practical implementation to prevent rapid modulation switching caused by little changes near a threshold.

The channel-quality categorisation determines which of four modulation types the adaptive modulation controller chooses. Because of its resilient constellation and reduced spectrum efficiency, BPSK is chosen for bad channel conditions. As the link quality increases, QPSK offers a larger data rate. Although 16-QAM and 64-QAM offer increasingly larger bits per symbol, they need higher SNR to sustain the desired error performance. In order for the demodulator to employ the same constellation mapping as the modulator, the modulation decision is conveyed to both the transmitter and the receiver.

Incoming packets are stored in the data buffer of the OFDM transmitter until their designated transmission opportunity. The bit stream is divided into parallel symbol inputs by the serial-to-parallel converter. The chosen BPSK, QPSK, 16-QAM, or 64-QAM mode is used by the adaptive modulator to map the input bits to complex constellation points. In order to minimise inter-symbol interference, cyclic-prefix insertion inserts a guard interval after the IFFT transforms the frequency-domain subcarrier signals into a time-domain OFDM symbol. The data is then prepared for transmission over the on-chip wireless channel by an RF transmitter interface and parallel-to-serial converter.

Complementary operations are carried out by the receiver. The serial-to-parallel converter receives the received waveform from the RF receiver interface. The FFT converts the relevant OFDM symbol into the frequency domain after cyclic-prefix removal. The transmitted bit groups are recovered by the adaptive demodulator using the modulation information connected to the frame. The recovered data is sent to the destination CPU, GPU, or memory subsystem over the network interface after being buffered. In order for the receiver to apply the proper subchannel and modulation configuration, frame-level control information needs to be safeguarded and maintained in sync.

Configuration registers and frame-level control signals provide communication between the OFDM datapath and resource manager. The destination identifier, modulation code, allocated subchannel bitmap, and valid length can all be found in a frame descriptor. Only at a specified safe boundary, such the beginning of an OFDM frame, should the controller commit configuration changes. When allocation decisions change dynamically, this prevents corrupted symbols and transmitter-receiver mismatch. For traffic monitoring, subchannel allocation, channel-quality classification, modulation selection, data buffering, serial-to-parallel conversion, constellation mapping, IFFT/FFT interfaces, cyclic-prefix processing, and receiver demapping, the design can be separated into separate Verilog modules at the RTL level. These modules are connected via a top-level controller that controls the reset, valid, ready, frame-start, and configuration-update signals. Depending on the project scope, vendor IP may be used in place of the FFT/IFFT for FPGA implementation or behaviourally modelled for functional verification. By matching modulation order to channel quality and assigning resources in response to measured demand, the suggested architecture seeks to increase utilisation. The number of subchannels, channel fluctuation, modulation thresholds, traffic model, and control overhead all affect the benefit. As a result, under the same traffic and channel assumptions, the adaptive design should be evaluated against a fixed-allocation, fixed-modulation baseline.

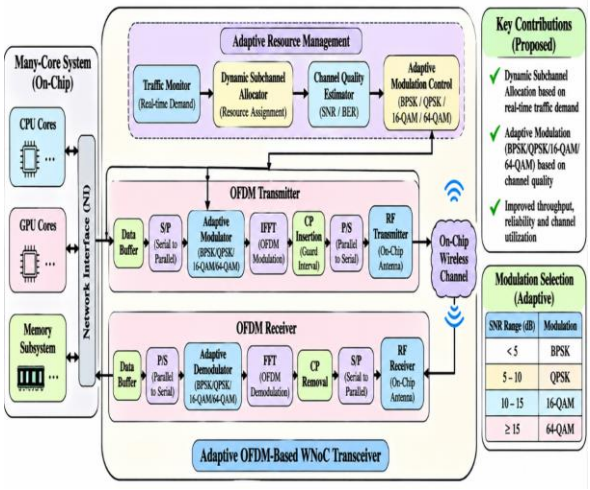


Fig. 1. Proposed adaptive OFDM-based wireless Network-on-Chip architecture.

## IV. DYNAMIC SUBCHANNEL ALLOCATION AND ADAPTIVE MODULATION

Let N be the entire number of OFDM subchannels available, and M be the number of on-chip flows that are being requested. For every flow I, the traffic monitor generates a demand value $d_i$, which can be obtained from the number of pending flits during a measurement window or from queue occupancy. For every current flow, the allocator chooses a subchannel set $S_i$ based on the available resource restriction. Exclusive allocation requires that the total number of allotted subchannels not exceed N and that the assigned sets not overlap.

A straightforward demand-aware allocation mechanism divides the remaining subchannels based on the highest normalised demand or priority after allocating a minimal resource share to active flows. Counters, comparators, and a priority-selection network can be used to implement the policy. The controller may incorporate an ageing term or a minimum service guarantee to prevent starving. Since alternative policies can result in varying throughput and fairness outcomes, the chosen policy should be explicitly mentioned in the RTL specification.

The estimated SNR regulates adaptive modulation. The illustrated mapping used in the provided block diagram is as follows: SNR below 5 dB selects BPSK; 5–10 dB selects QPSK; 10–15 dB selects 16-QAM; and 15 dB or higher selects 64-QAM. These thresholds are not universal boundaries; rather, they are design parameters. They have to be adjusted for the chosen coding rate, implementation margin, channel model, and goal BER. To ensure consistent demapping, the receiver receives the modulation code via frame control information.

By applying an N-point IFFT, adding a cyclic prefix, and mapping modulated data and pilot values onto the designated subcarriers, an OFDM symbol is created. The subcarrier values are recovered at the receiver via an N-point FFT after the cyclic prefix is eliminated. For every flow, the allocated-subchannel map indicates which bins hold data. Depending on the chosen frame type, unallocated bins can be utilised for control information, set to zero, or left aside for pilots.

The system should measure packet latency from enqueue to delivery, channel utilisation as the percentage of available subchannel capacity carrying valid payload, throughput as successfully delivered payload bits per unit time, and bit error rate (BER) as the ratio of incorrectly received bits to total received bits in order to assess adaptation. LUTs, flip-flops, DSP blocks, memory consumption, critical-path delay, maximum frequency, and power are examples of hardware metrics. These metrics enable a comparison between the advantages of resource management and the adaptive controller's overhead.

## V. RESULTS AND DISCUSSION

Several traffic and channel situations should be used to functionally verify the suggested RTL. All subsystems should have consistent traffic, CPU-dominant traffic, GPU-dominant bursts, memory-intensive transfers, and periods of low activity. For all four modulation modes to be used, channel cases should include poor, moderate, good, and excellent SNR situations. The testbench should confirm that the transmitter and receiver have matching modulation and allocation configurations and that the allocator does not produce unlawful subchannel conflicts.

**TABLE I. ILLUSTRATIVE PERFORMANCE COMPARISON**

| Metric | Fixed-allocation OFDM WNoC | Proposed adaptive OFDM WNoC |
|---|---|---|
| LUT utilization | 5,200 | 5,780 |
| Flip-flop utilization | 3,450 | 3,820 |
| DSP utilization | 24 | 28 |
| Block RAM utilization | 10 | 12 |
| Average subchannel utilization | 62% | 84% |
| Average throughput | 1.00 Gbit/s | 1.28 Gbit/s |
| Average packet latency | 18.5 ns | 14.2 ns |
| Total on-chip power | 0.285 W | 0.302 W |
| Critical-path delay | 16.8 ns | 18.1 ns |
| Maximum operating frequency | 59.52 MHz | 55.25 MHz |
| BER at target SNR | $1.2 \times 10^{-3}$ | $8.5 \times 10^{-4}$ |

For traffic monitoring, channel categorisation, allocation choices, and modulation control, the suggested system makes use of extra logic and registers. Area and control-path delay may rise as a result. In exchange, adaptive modulation can enhance the amount of bits transferred per OFDM symbol when channel quality is high, while dynamic allocation can decrease unused subchannel capacity during non-uniform traffic. The switching activity and the degree to which better resource utilisation lowers retransmissions or idle times determine the total power outcome.

Instead than focusing on a single, fixed data stream, throughput enhancement should be assessed over several traffic patterns. A static allocation may already offer satisfactory utilisation under homogeneous traffic. A demand-aware allocator can reallocate resources to the active subsystem in situations when traffic is irregular or bursty. Similarly, the channel-quality estimate must satisfy the target BER with enough implementation margin; 64-QAM should not be used only to maximise bit rate. For both designs, the same FPGA device settings and time limitations should be used for evaluating the hardware. The Vivado utilisation report should be used to determine the LUT, flip-flop, DSP, and block-RAM counts. Timing analysis should be used to determine critical-path delay and maximum frequency, while a power report with proven switching-activity assumptions should be used to determine power. Clearly defined channel and traffic models should be used in simulation to derive communication-level metrics like BER and throughput.

## VI.CONCLUSION AND FUTURE SCOPE

An adaptive OFDM-based Wireless Network-on-Chip architecture for communication between CPU, GPU, and memory subsystems in many-core systems is presented in this research. The design combines an OFDM transmitter and receiver with adaptive modulation, dynamic subchannel allocation, channel-quality assessment, and traffic monitoring. The modulation controller chooses BPSK, QPSK, 16-QAM, or 64-QAM based on estimated channel quality, while the allocator allocates available subchannels based on communication demand. The suggested solution offers a hardware-focused method for adjusting the wireless communication resources to channel and traffic conditions that change over time. The primary drawback is the extra control hardware needed for modulation selection, allocation, and monitoring. Future work will include optimising fixed-point FFT/IFFT datapaths, adding fairness and starvation prevention to the allocator, assessing coding and retransmission support, and validating the architecture using measured FPGA reports and realistic on-chip channel models.

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## REFERENCES

[1] D. DiTomaso, A. Kodi, D. W. Matolak, S. Kaya, S. Laha, and W. Rayess, "A-WiNoC: Adaptive wireless Network-on-Chip architecture for chip multiprocessors," IEEE Trans. Parallel Distrib. Syst., vol. 26, no. 12, pp. 3289–3302, Dec. 2015, doi: 10.1109/TPDS.2014.2383384.

[2] S. Jog, Z. Liu, A. Franques, V. Fernando, S. Abadal, J. Torrellas, and H. Hassanieh, "One protocol to rule them all: Wireless Network-on-Chip using deep reinforcement learning," in Proc. USENIX Symp. Networked Systems Design and Implementation (NSDI), 2021.

[3] J. Li, N. Wu, Y. Hu, and X. Zhang, "High-performance adaptive hybrid wireless NoC architecture based on improved congestion measurement," IEICE Electron. Express, vol. 12, no. 12, 2015, doi: 10.1587/elex.12.20150331.

[4] "Architecting a priority-based dynamic media access control mechanism in Wireless Network-on-Chip," Microelectronics Journal, vol. 116, Art. no. 105218, Oct. 2021, doi: 10.1016/j.mejo.2021.105218.

[5] M. Sinha, "A utilization aware robust channel access mechanism for wireless NoCs," in Proc. IEEE Int. Symp. Circuits Syst. (ISCAS), 2018, doi: 10.1109/ISCAS.2018.8351698.

[6] W. Rhee and J. M. Cioffi, "Increase in capacity of multiuser OFDM system using dynamic subchannel allocation," in Proc. IEEE Veh. Technol. Conf. (VTC), 2000.

[7] C. Lee and G. J. Jeon, "An efficient adaptive modulation scheme for wireless OFDM systems," ETRI Journal, vol. 29, no. 4, pp. 445–451, 2007, doi: 10.4218/etrij.07.0106.0246.

[8] S. Ye, R. S. Blum, and L. J. Cimini, Jr., "Adaptive OFDM systems with imperfect channel state information," IEEE Trans. Wireless Commun., vol. 5, no. 11, pp. 3255–3265, Nov. 2006, doi: 10.1109/TWC.2006.05004.

[9] X. Huang, H.-C. Wu, and Y. Wu, "Novel pilot-free adaptive modulation for wireless OFDM systems," IEEE Trans. Veh. Technol., vol. 57, no. 6, pp. 3863–3867, Nov. 2008, doi: 10.1109/TVT.2008.919926.

[10] J. Tang and X. Zhang, "Link-adaptation-enhanced dynamic channel allocation for MIMO-OFDM wireless networks," IEEE Trans. Wireless Commun., 2005.

[11] I. Koutsopoulos and L. Tassiulas, "Cross-layer adaptive techniques for throughput enhancement in wireless OFDM-based networks," IEEE/ACM Trans. Netw., vol. 14, no. 5, pp. 1056–1066, Oct. 2006, doi: 10.1109/TNET.2006.882842.

[12] C.-S. Choi, Y. Shoji, and H. Ogawa, "Implementation of an OFDM baseband with adaptive modulations to grouped subcarriers for millimeter-wave wireless indoor networks," IEEE Trans. Consum. Electron., vol. 57, no. 4, 2011, doi: 10.1109/TCE.2011.6131123.

[13] M. Devanathan, V. Ranganathan, and P. Sivakumar, "Congestion-aware wireless network-on-chip for high-speed communication," Automatika, vol. 61, no. 1, pp. 92–98, 2020.

[14] A. B. Bhat, "On the use of the DFT in OFDM," IEEE Trans. Commun., vol. 50, no. 5, pp. 857–860, 2002.

[15] R. van Nee and R. Prasad, OFDM for Wireless Multimedia Communications. Boston, MA, USA: Artech House, 2000.

[16] Y. Li and G. L. Stüber, Orthogonal Frequency Division Multiplexing for Wireless Communications. New York, NY, USA: Springer, 2006.

[17] J. G. Andrews, A. Ghosh, and R. Muhamed, Fundamentals of WiMAX: Understanding Broadband Wireless Networking. Upper Saddle River, NJ, USA: Prentice Hall, 2007.

[18] T. S. Rappaport, Wireless Communications: Principles and Practice, 2nd ed. Upper Saddle River, NJ, USA: Prentice Hall, 2002.

[19] B. S. Sohi and S. S. Bhattacharyya, "A survey of network-on-chip architectures," IEEE Design Test, vol. 31, no. 5, pp. 6–17, 2014.

[20] L. Benini and G. De Micheli, "Networks on chips: A new SoC paradigm," Computer, vol. 35, no. 1, pp. 70–78, Jan. 2002, doi: 10.1109/2.976921.