A Review of System on Chip (SOC) Applications in Internet of Things (IOT) and Medical

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Abstract
Internet of Things is the network cloud-based kingdom which combines a large number of cores on one unique platform for Multiprocessor System on Chips, which makes it rising methodologies in the mentioned domain. Nonetheless, the main metric which limits the functionality of multiprocessor system on a chip is the interconnects web between cores on a chip. Heterogeneous Network-on-Chip Simulator have come out as a feasible way to resolve these problems. Existing health applications are mainly driven by fraud issues and the privacy of patients also suffered as a result. This review introduces a brief overview of the existing application of System on chip in IoT and the Medical field as well as their methodologies. A comprehensive study about key features of the system like power, throughput, latency gives keen insight of structures of HNoCs and ECG-based identification systems as well. This work also provides an insight into the currently available achievements in Heterogeneous Network-on-Chip Simulator interconnects, data acquisition and analysis methodologies of patients. The biometric solutions are the best serving for all those health applications which are based on the Internet of Things.

Keywords
Internet of Things, Multiple-Processor System on Chip, Optical/Hybrid Network on Chip, Compressive sensing, Zynq SoC board, Reconstruction flow, Pattern identification, Sectioned Unidirectional Optical Ring for Multiprocessor.

1. Introduction

SOC is a hardware platform for different modules so that they can communicate with each other effectively and efficiently. It includes central processing units, input/output ports, storage memories, digital to analog , analog to digital converters, signal processing and image processing, etc. With the increasing trend of research in SOCs due to its pliability and compatibility for real-time implementation in various application areas i.e., high processing speed, image and video processing, Artificial Intelligence (AI), neural networks, security validation and verification, energy systems, automatic systems, IoT, and medical [1-2]. Because SOCs are hardware-based systems their security is the main concern in any of the mentioned applications. These systems are no more trustworthy because of hacking and stealing data. So, the trend is moving towards other more secure platforms i.e., IOT along with the hardware [2].

Because the need for large memory for data storage and processing is dramatically increasing with each passing day, IoT is being used for portable devices. This is done only on the hardware which is a very complex task. So, in addition to the hardware, this network application, i.e., IoT is configuring for memory resolution and data security. [3].

Internet of Things is an online platform for intercommunication of different types of systems i.e., computer systems, SOCs, embedded systems, etc via network globally. This platform is secure and has its own identity in the IT field. The main purpose of the IoT is the remote access of data for continuous monitoring [4]. The beauty of SOC-based IoT systems is that its records can be monitored any time for better understanding and analysis of the results as well as privacy is 100% guaranteed in it [5].

With the increasing world strength day by day, issues related to human health are increasing and expenditure on medical facilities related to patient's health is also raising remarkably. Due to this, it is a very big challenge for the government, medical health boards, hospitals, and health care centres to serve effectively with patients. Efforts are needed for effectively resolving these issues. Thus, it is a requirement to explore all the existing efficient and powerful embedded SOCs', and IoT-based platforms in deep detail. So, that aging population health issues can be served effectively. They provide well secure and durable services [4].

This paper presents a review of MPSoCs based IOT interconnects because MPSoCs are trending key technology for the IoT realm, which are integrating thousands of cores on a single platform. The interconnects between the cores making a network, are a key performance-limiting factor. To resolve this problem hybrid topologies interconnects are used for NoCs. It is very challenging to do for MPSoCs, CMPs (chip multiprocessors), and multicore systems. In Medical the sensor-based SoC patient's health monitoring system for IoT-based applications aue used to avoid fraud issues and fake reports. The main objectives of this paper are given below.

1. To review the recent existing architectures of NoCs.
2. To through a light on the performance matrices of any of the SoC-based systems i.e., throughput, latency, and power consumptions.
3. To provide future challenges and problems of hybrid architectures.
4. To analyze the corruption problem biometric solution related to patient's health.
5. To understand the data transmission through compressive sensing (CS).

This review article is sorted out as follows. Section II is basic knowledge about hybrid NoCs, section III proposed designs, section IV is about the performance comparison of solutions of MPSoCs interconnects for IoT, section V patient health monitoring schemes review, section VI system and implementation and section VII conclusion of the paper.

2. Basics of Hybrid NOC

Hybrid means multiple, many, more than one. NoC is a network on a chip it responds towards the inter-connects solution of multicore processors SoCs which are combined. The various forms of communication adopted by the different researchers, but optical communication is used here. This system comprises of four basic modules Laser source, Coupler, Microring resonator, and Silicon Waveguide. Every module is displayed in **Figure 1** [6] which is the representation of off/on-chip components of the system. Optical networks on chips are a new rising trend to fulfil the future MPSoCs like low power, minimal latency, and ultrahigh power [9-11]. Local distance communication can be done through an Electric network-on-chip but for long-distance and wide communication, Optical NoCs are used [12].

Laser is the source of the continuous light wave of specific wavelengths. After wave production wavers are encoded and transformed into an electronic data form. Then it is guided through a waveguide to light detectors called photodetector. The laser source has two possibilities either it is an On-Chip or Off Chip module. Here the Off Chip is being used via optical links. It produces waver so several wavelengths generally represented as $\lambda1, \lambda2, \ldots\ldots, \lambda n$. These wavelengths are combined at a coupler and passed through waveguide-optical wires, to interconnect on-chip. The signals may be suffered from the opposition produced by a waveguide. The principle of carrying a wave in it is wave multiplexing.

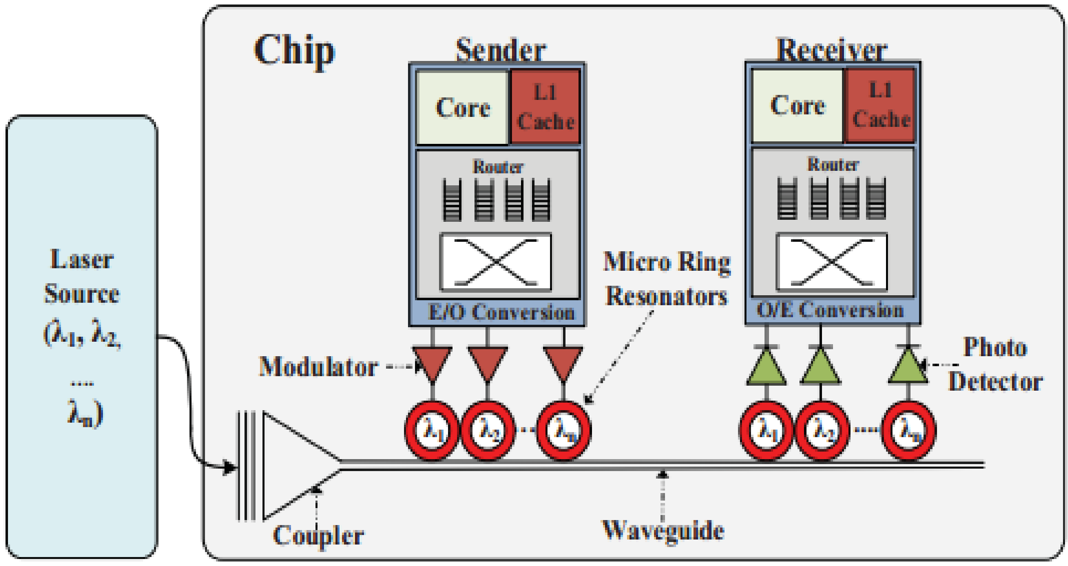

Figure 1. Basic Module of Optical Component of On Chip System

The waveguide capacity of transferring signal is TERA bites [8]. A micro resonator is one of the most important modules because it is compatible with CMOS. It can modulate and demodulates the signals. It converts electrical to an optical signal. Because optical links are being used, these links are compatible with the optical nature of signals. It also acts as a photodetector. Whenever the wavelength of the inserted signal becomes equal with the resonating frequency it acts as an absorber of that wavelength and drops it out via drop port as shown in **Figure 2**. Other signals travel via port [7]. A coupler is the major component of the device because it provides the configuration environment for physical optical devices.

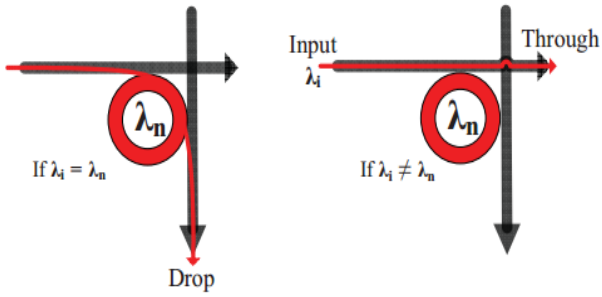

Figure 2. Drop and Through Ports

3. Design Proposals

Different design proposal of optical NoCs for inter-connects between multicore processors SoCs for IoT is discussed here. The major problem of these systems is static power consumption. This metric has a vital role in the performance of the systems. So, to keep the power consumption low many of the proposed designs were presented in the previous years. Every HNoCs/Photonic NoCs needs a setup i.e., path setup. Before transmission of the data, a switched network is required, or a specific waveguide architecture is needed for token arbitration. **Figure 3** represents a 4x4 mesh type architecture having electrical layers. These layers provide control for path data before transmission. When this process gets completed paths build then transmission of data is via optical port. Every ONoCs (Optical network on chip) of MPSoCs interconnects as IOT use the wave division multiplexing (WDM) [12].

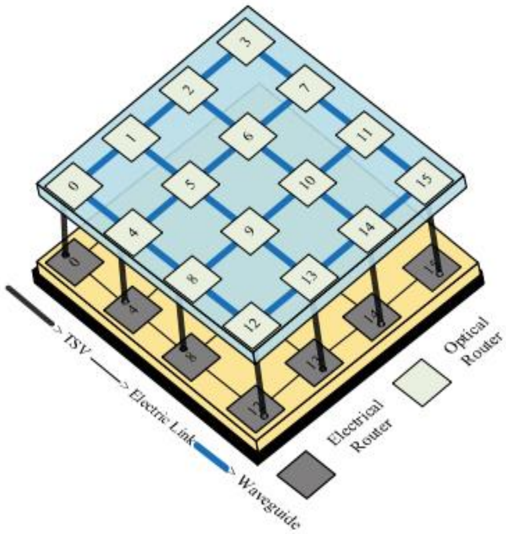

Figure 3. 4x4 Mesh Architecture

The principle of optical communication is wavelength routing which is dependent on these wavelengths $\lambda 1, \lambda 2, \ldots\ldots, \lambda n$. There is the chance of collision between signals of communication among source and destination. To avoid this MR-micro resonator filters are used. It works in the switching mode between the source and destination. There is also a chance of collision between signals at networks of interconnects, so to avoid these optical crossbars are used. Some architectures have been studied like Single Write and Single Read (SWSR), Multi Writer Multi Reader (MWMR) [2]. When MR increases the power, its consumption also increases. Keeping in mind these issues has been resolved by various wavelength routing and router design like Snake, λ-router, Cygnus, CRUX, GWOR, ORNoCs [3-6]. As every destination has a separate wavelength user/sender modulates the data according to a specific wavelength of destinations for the successful and complete transfer of the data. Energy is improved in many architectures with the help of LumiNoC method [7]. A well-known architecture named as CORONA for ONoCs with multiple write single read principle is used for token ring arbitration methods [8]. Flexishare uses optical crossbar architecture in multi-stage [9]. Quarten Topology is the optimized arrangement of ONoCs which is designed for higher efficiency and lower consumption of power [10]. With the reduction of path length, wavelength count, and MR, the Amon method is proposed which transfers the efficient power [12]. Latency and power optimization can be done by merging TDM and WDM with optimal signal-to-noise ratio SNR [2-3]. Bandwidth and latency have been optimized by merging RPNoC, WDM, and SDM [3-4].

Link establishment is very important for communication. This has been done through the link reservation process. This process attains through REQ/ACK signal packet interchanging among destination and source. It permits communication type i.e., collision-free rather than the switching, same channel is employed for both waveguide and bandwidth for data transfer. But, in this situation, only one source is capable of data transmission on a specific wavelength. So, the proposed design i.e., SUOR (Sectioned Unidirectional Optical Ring for Multiprocessor), Amon, and QuT as discussed earlier gives significantly improved results [1-5]. Amon's λ-set is for addressing four destinations that is why it reduces to N/4. The Control network boost up the reduction of MRS count but it has performance constraints. To get high throughput and efficiency, SUOR is used which partitioned the data links dynamically into several parts/segments [34]. QuT further transfers best control networks that provide certain wavelengths on waveguides i.e., optical paths. Each node of a certain waveguide utilizes its distinct λ-set for communication which more decreases in number of waveguides and filters i.e., N/8. Advance architecture MRONoC decreases load upon wavelength value by giving equal/balanced between and waveguides wavelength count which in return reduces the scalability problems [36]. As photonics systems trend is raising but upon deep review it was found that hybrid NoCs are more efficient for interconnects of MPSoCs because PNoCs consume more static power [48]. That is why HNoCs have a better future for MPSoCs. **Figure 4** shows the general hybrid architecture in four layers i.e., electrical layer and heat sink, optical, electrical optical interface.

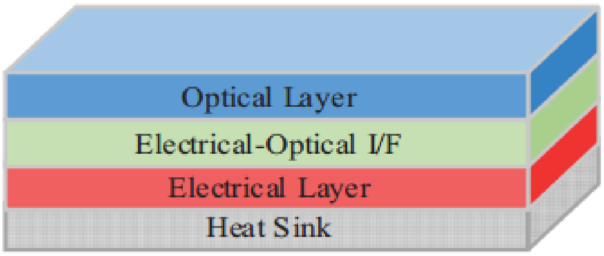

Figure 4. Hybrid Architecture NoCs for MPSoCs

Meteor is a one HNoCs architecture which is variable cluster size it suggests effective design nodes are 16 in count i.e., 64 nodes of 4x4 small-mesh [9]. With the use of four MWBR buses, it is easy to reach optical channels through gateway routers for inter-cluster transmission [5].

4. Relation of MPSOCS Interconnects Solution

This section covers the comparison of energy and power of ONoCs & HNoCs structures. It is very challenging to get power efficient interconnection network in the future for MPSoCs. Photonic NoCs energy consumption is 64-DWDM in different bus architectures [2]. **Figure 5** shows the power utilization of MWSR, SWMR, and MWMR.

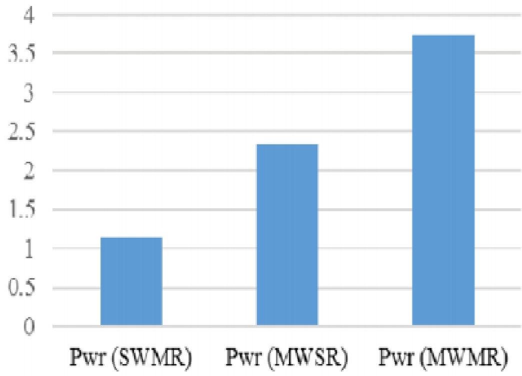

Figure 5. Hybrid Architecture NoCs for MPSoCs

Insertion loss is maximum in each Olink tells us each wavelength output power. Currently, device losses and laser sources require a prominent and well-defined constraints scheme for unnecessary power losses. Also, maximum insertion loss depends upon the wave count and number of readers [3]. With an increase in the number of wavelengths laser power consumption exponentially increases, MR increases, cross talk noise raises. As a result, reducing the amount of wavelengths is critical as in SWMR. **Figure 6** demonstrates laser power of ONoCs and HNoCs for MPSoCs respectively.

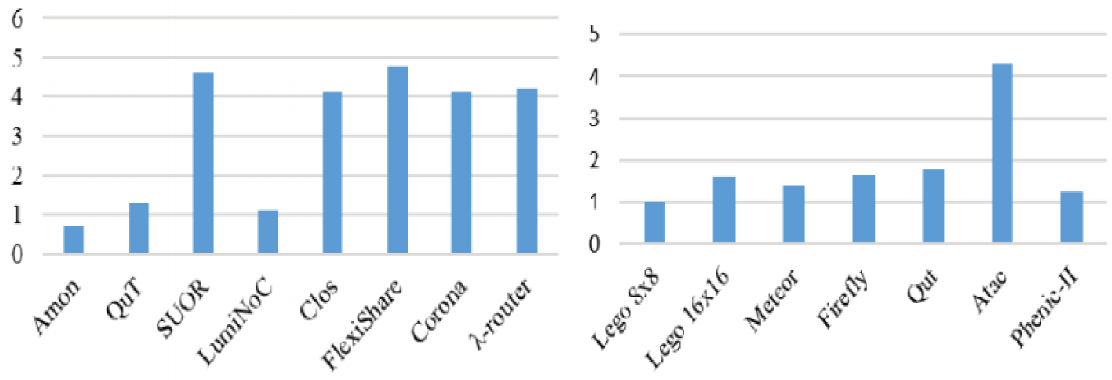

Figure 6. (a) Relation of Laser Losses in Various architectures for PNoCs of MPSoCs (b) Relation of Laser Losses in Various architectures for HNoCs of MPSoCs

5. Patient Health Monitoring Schemes

This section covers up a review upon health monitoring scheme i.e., biometric. This is done by using a zynq SoC board along with the IoT. In the normal way data collection related to patient's health is an ordinary manual way. This serves as an issue as sometimes sudden action is needed and due to unavailability of medical panel patient can become critical. Sometimes patient uses same devices for monitoring due to which inaccuracies happen. For this, remote monitoring and a 24hrs continuously automatic updated platform are being used along with the SoC hardware.

In this way of monitoring scenario, every patient has some specific sensor devices which are linked together with a unique identifier for sorting at cloud server [4]. The recorded accuracies are the main concern for health monitoring platforms for identification of separate patient health and sort out patient's population. So, the solution regarding these issues is by using compressive sensing (CS) [5]. The reason for this scenario is to decrease the strength of samples transmitted over a single device and network. Also, identify different individuals by effective pattern recognition. CS gained remarkable attention in the field of signal processing [6]. Now data is collected in compressed form rather than a spaced point form, where every measurement is the weighted summation of all signals. The beauty of compressed data collection is that it has the capability of optimal recovery of original data when complex reconstruction algorithms are being used i.e., orthogonal matching pursuit [2]. CS targets to remove difficulties from the sensor (i.e., resource-consuming increases metrics) losses with relaxing constraints.

On the other hand, mostly pattern recognition methods are a key principle of working of monitoring systems to compare the given data and acquired signals dataset. Identification of systems are dependent on biometric characteristics which works on the principle of distinct and intrinsic behaviour of patients' physiological characteristics like (gait, interaction gestures, and voices), (DNA, ECG, Iris, and Face). Biometric systems give acceptable and relaxed constraints relying on the requirements. ECG-dependent identification can be found by the backtracking work of Biel et al [8] and Irvine [9]. The key purpose of this is to identify individuals based on ECG i.e., biometric sensing here. Two methods followed (i) characteristic-based and (ii) waveform-based [6]. Characteristic-based monitoring of ECG uses fiducial points, which corresponds to PQRST curves in the graph [6]. Fiducial points are those heart points that are involved in electrical activity. Individual identification uses the duration of amplitude and fiducial point's correlation [2].

A unified framework of a biometric system based on ECG is exploiting the compressive sensing methodology. The purpose is to demonstrate an SoC solution that decreases all consumption of power and other metrics. Usually, samples are collected based on their bandwidth rate with its width W and sampled frequency $f_s >= 2W$. Normally acquired data are large/big and useless/redundant, it is packed without redundant data [3]. Considering the orthogonal basis $\{\Psi i\}n\ i = 1$ that spans Rn, any one of the signals $x \in Rn$ can be interoperated as a linear fusion of the elements of Ψ with the vector elements $s = [s1, s2, \cdot\cdot\cdot, sn]^T$ such that $x = Pn\ i = 1$. The signal x is considered as k-sparse if the vector s has only k << n but non-zero entries. The Ψ matrix is known as the sparsifying matrix in the context of CS. Discrete cosine transforms (DCT) and discrete wavelet transforms (DWT) are two examples of sparsifying bases commonly used in biomedical signals. [2-4].

The Compressed Sensing encoder works with both capturing and compressing to directly obtain the signals in compressed form. In CS encoder module, the multiplication of input signal x with a tall random sensing matrix is done, hence, the process of acquisition can be modelled as:

$y = \Phi x = \Phi \Psi s = \Theta s$ (1)

where $\Phi \in R^{mxn}$, shows the data acquisition and compression sensing matrix. the compression ratio (CR) is defined as the ratio $\frac{m}{n}$.The sensing matrix design should constitute two conditions, the restricted isometry property (RIP) and incoherence [5]. Both conditions ensure that random matrices are explored. Bernoulli matrices also have the same level of assurance. To get fast reconstruction of signals convex optimization and greedy algorithms are used. The data usage for experiments is taken from the Physio Net-MIT Arrhythmia Dataset which gives free internet access to ECG multichannel. **Figure 7** presents different data recordings from the MIT database. **Figure 8** illustrates the system design framework

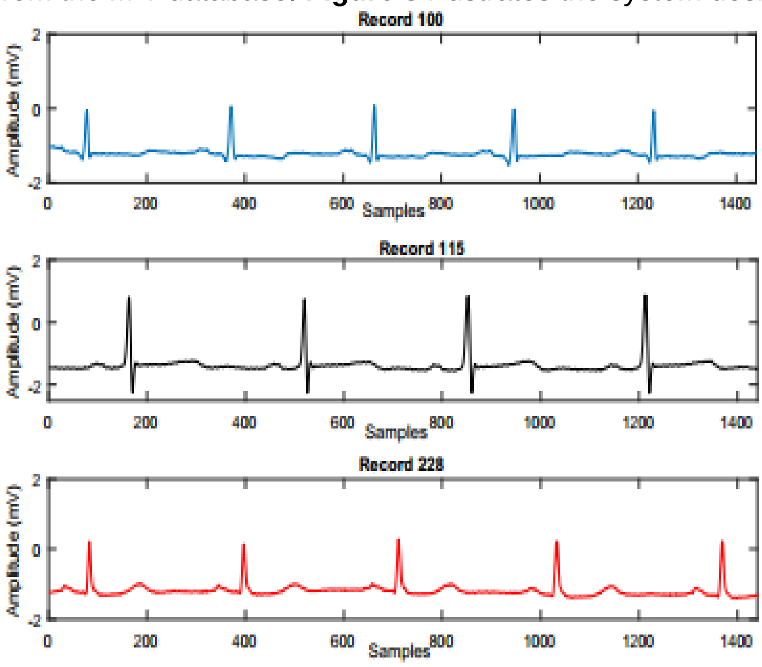

Figure 7. Different Patients Values Record from MIT Database

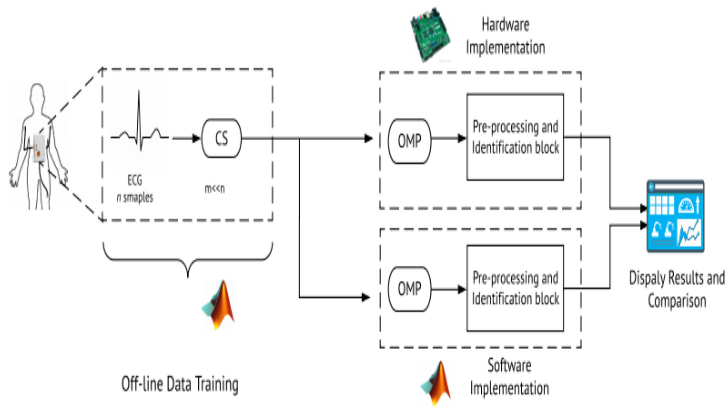

Figure 8. Relation Design of System

MATLAB Monte Carlo simulation is best in this regard on the data of the MIT database. The percent root-mean-square difference (PRD), which can measure the quantity of distortion in its recreated ECG signals, is used to assess reconstruction quality.PRD is associated through the computer-based diagnosis i.e. heart rate estimations. Mathematically,

$$\mathrm{PRD}(\%) = 100 \times \frac{||x - x'||^2}{||x||^2} (2)$$

Since x and x' are the reconstructed signals. **Figure 9**-part **a** represents the PRD wave forms. 1-40Hz band pass filter will be used to filter ECG recordings. Further, the process is followed by algorithm to detect peaks. The reconstruction process if signal using CS, is very large time-consuming process. **Figure 9**-part **b** shows the relation of reconstruction and identification process of patients.

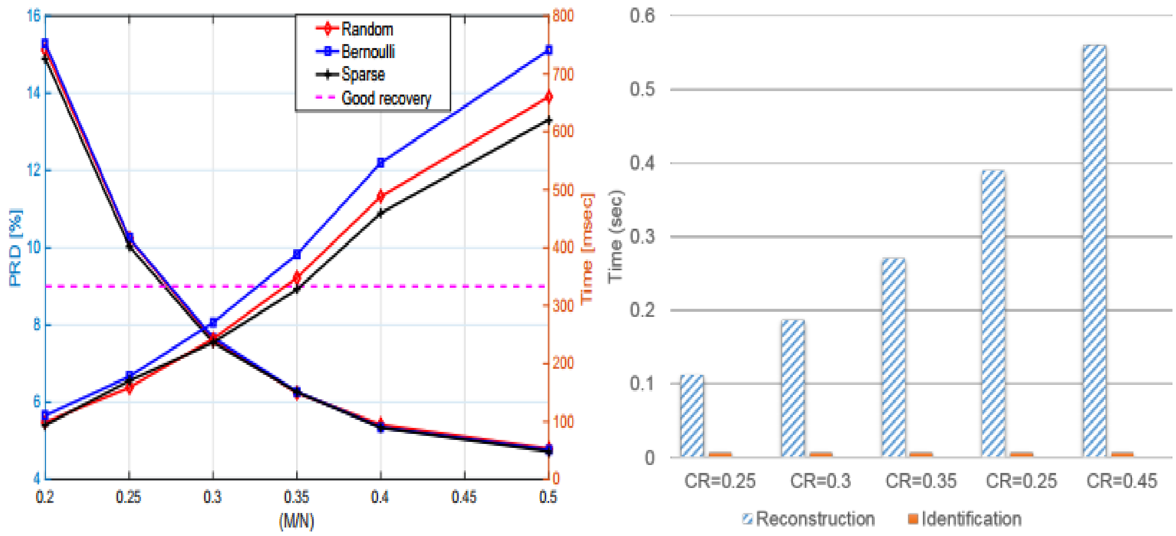

Figure 9. (a) Reconstruction Quality of signal with different PRD (b) Reconstruction of ECG signal Time Response Representation

6. System and Implementation

The proposed hardware consisted of four major parts.

i. Loading of ECG signal.
ii. Reconstructing ECG signal.

iii. Detection of R peak.
iv. Classification using KNN classifier.

Firstly, CS signal has been loaded. For signal reconstruction, the OMP algorithm is applied to a compressed signal. Pan-Tompkins worked on the signal for R peak detection. For classification of data clusters a KNN classifier was used in the end. The whole system is modelled in Vivado HLS in C++ programming [2]. Most of the time consumption was done by Signal reconstruction algorithm. The Zynq SoC FPGA is used for hardware implementation along with SDSoC (v2017.2) [4]. **Figure 10** shows the blocks for loading ECG signals, extraction of peak, and KNN classification that were solely implemented on the PS7[4].

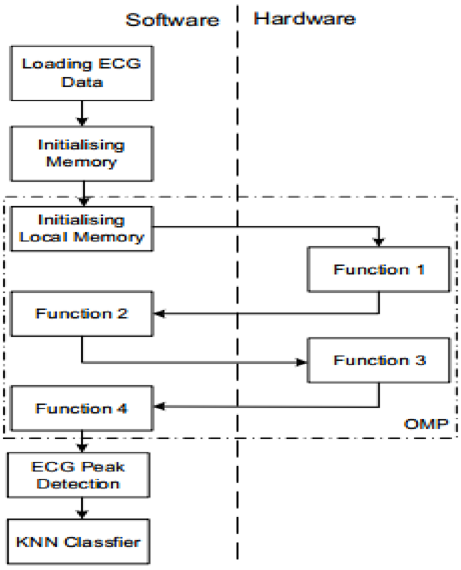

Figure 10. Overview of the System [4].

7. Conclusion

This paper demonstrates a detailed and brief review of SoCs in the field of IoT and medical. It is being observed in combined literature review how SoCs becomes a focus and key point for researchers in many past years. Nowadays many efforts are under progress related to cloud-based storage to minimize human interference. So, that efficient communication, as well as data, is acquired and based on this data identification of individuals can be done. In IoT, ONoC and HNoCs architecture has been reviewed in different system metrics like power efficiency and explained various summary and design structures of different parameters for optimization i.e., throughput, latency and power/energy has been provided. During the review about both ONoCs and HNoCs for Multicore Processors SoCs interconnects for IOT communication interrupted due to static power problem, optical losses, and waveguides large count leads to overheads of more power. It is concluded that the evolution of HNoCs for MPSoCs in IoT motivates the designers and researchers to use the attributes of the electrical area and combines with optical methodologies to decrease the communication latency margins and effectively power overheads minimize in IOT field for cloud-based storage and communication between multiple cores interconnection on a network. In the medical area, the union of ECG biometric and the concept of CS presents, an appreciating technique that provides a solution that is feasible for both privacy and huge data communication problems facing the connected health applications. The paper demonstrates frameworks-based SoCs along with IoT cloud-based storage for patient information that grips a CS scheme of acquisition and a simple machine learning tool which is appropriate to find out patients from their acquired data, which helps in diagnosis and treatment of specific patients remotely.

List Of Symbols

λ	Wavelength (meters)
f_s	Sampled Frequency
Ψ	Orthogonal Basis
$\frac{m}{n}$	Compression Ratio

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