A Study of Technology Roadmap for Application-Specific Integrated Circuit

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ABSTRACT

The International Technology Roadmap for Semiconductors (ITRS) designs roadmap for the researchers and engineers in the ASIC technology industry every few years. This group is divided into seven focus teams. In this paper, I review the future goals and challenges provided by the Systems Integration, Outside System Connectivity and the Factory Integration group[1].

1. INTRODUCTION

In order to ensure a systematic and rapid growth in the ASIC technology industry, there is a need to analyze the demands from consumer end and create short term higher level goals for researchers and engineers in the industry. To this end, the Semiconductor Industry Association (SIA) has taken up the challenge to create these roadmaps every few years. Consequently the International Technology Roadmap for Semiconductors (ITRS) which is sponsored by industry leaders in five countries including Europe, Japan, Korea, Taiwan and United States proposes challenges and goals that need to be met to ensure the desired level of progress.

The ITRS is divided into 7 teams namely System Integration, Heterogeneous Integration, Heterogeneous Components, Outside System Connectivity, More Moore, Beyond CMOS and Factory Integration. While these groups have their own targets and activities, there is an interdependence between these groups. This interdependence is as shown in fig. 1.

In this report, I review the literature provided by the Systems Integration, Outside System Connectivity and Factory Integration groups. These groups seem to be closely related to the area of systems research. Since I specialize in wireless systems and networks, the work done by these groups is very relevant to my research which is the main reason for choosing them.

In section 2, review of the works of system integration group is provided. Section 3 describes a review of outside system connectivity while Section 4 studies Factory Integration. References are provided in section 5.

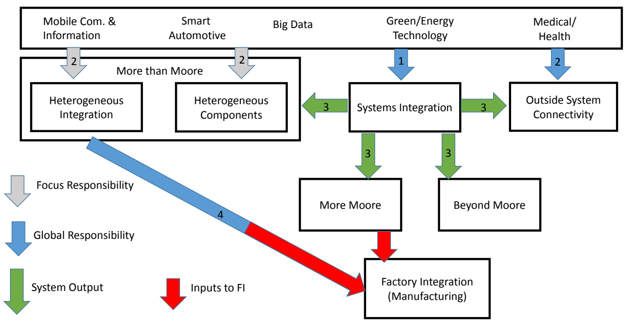

Figure 1: Focus teams in the ITRS and their dependencies [5]

2. SYSTEM INTEGRATION

The objective of this group is to identify the trends in system products that drive ITRS technologies. The target systems are smartphones, datacenters and microservers and IoT smart objects. The prime research direction involves extraction and analysis of data, identification of performance metrics, using models to understand issues, and identifying areas that need immediate investment to ensure smooth progress in the future.

To do so they divide their work into the following sections:

1) Smartphones: For smartphones, the group identifies image processing, sensing and data analysis and compact integration of devices into a package as the demands of the future obtained from an analysis of the present market trends. Specifically, they highlight the need for research and development in computer vision, data mining and MEMS integration as the key requirements. They highlight the fact that with the advent of wearables, there is little clarity on how different functions will get divided into different system components. The key technologies that are driven by advancement in the smartphone domain are those related to system functionalities(e.g. number of cores in APs and GPUs),

[1]This document is an extended technical report of a work done in 2016

lithography, integration and packaging and those associated with advanced interconnect.

The group also identifies that the form factor for a smartphone architecture, the power consumption, increasing demand for high data rate and higher resolution in sensing hardware as the key challenges in the near future. It is interesting to note that while the group recognizes increasing bandwidth demands in cellular and wifi domains, it completely ignores new physical layer(PHY) schemes such as MU-MIMO [7–11, 13–16, 25] which not only demand advanced PHY with channel state based precoding capabilities different from those of omnidirectional single antenna systems [1, 12, 17–23, 23, 24]. Also, the new 3.5 GHz band that is released by Federal Communications Commission(FCC) for innovation and research (which would also change the challenges at the PHY) has not been addressed [2]. Based on their analysis, this group predicts two system level architecture: one targeted for 2019 (fig. 2) and one beyond 2020 (fig. 3). It also interesting to note in that upcoming technologies such as visible light communications (VLC) have not been addressed even in the architecture beyond 2020.

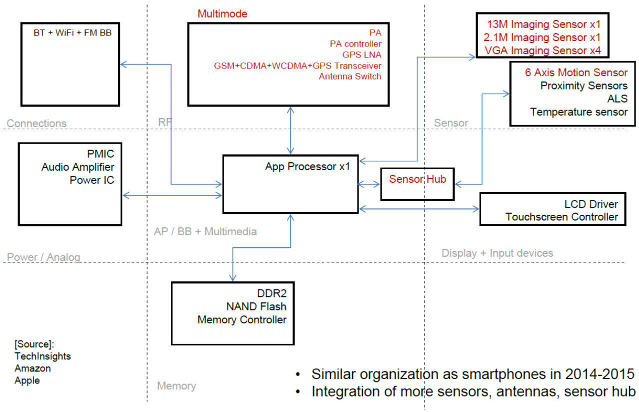

Figure 2: Smartphone architecture predicted for 2019 [5]

2) Datacenter and Microserver: This section focuses on the technologies that are required to interconnect different components in data centers and microservers. The group predicts that in the future, the electrical cables that connect different racks in a data center would be replaced by optical cables. There is also a possibility that they may be replaced by wireless point-to-point links operating in the 60 GHz band which has been ignored as well [4].

The group identifies that the same technologies that are driven by the smartphone development are also driven by the growing demands in the datacenter and microserver domain. The group predicts a near exponential growth in the demand for storage capacity, interconnect bandwidth and the computation capabilities at the data center end while a linear growth in the power demands. The group predicts a similar trend for microservers as well. The predicted architecture for microservers beyond 2020 is as shown in fig. 4. Just like the trends for data centres, the group predicts that the number of MPU cores and MPU frequencies will increase almost exponentially until 2019 while the maximum frequency will increase linearly.

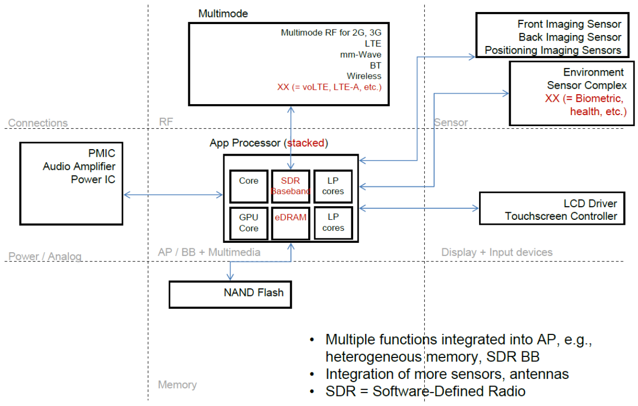

Figure 3: Smartphone predicted beyond 2020 [5]

3) IoT smart object: This section deals with connectivity, sensing, energy and security related issues for the Internet of Things components. The major concern here is power consumption. The group believes that the system performance must be increased while meeting power constraints on the system. The group shows a trend in the lowest system voltage and predicts a drop by a factor of 4 in 2017 under the assumption that energy harvesting is introduced in that year. This appears to be a very ambitious assumption for IoT given the large variety of devices it spans. The group identifies form factor and system level power as the key challenges. However, one of the main challenges in IoT is device level security and encryption since it involves a large number of wearable devices. This issue has not been fully addressed here.

3. OUTSIDE SYSTEM CONNECTIVITY

The outside system connectivity group focuses on the requirements and challenges involved in connecting devices involved in a system. The primary objective of this group is to enable efficient communication capabilities amongst the system components. For the next five years, they intend to focus on the Internet of Everything (IoT) and cloud communications. This involves filling the technology gaps required to interconnect the devices present in these two systems, including but not limited to sensors, that are useful for the areas of mobility, energy, health, etc.

To develop novel solutions, the group divides their work into two prime areas:

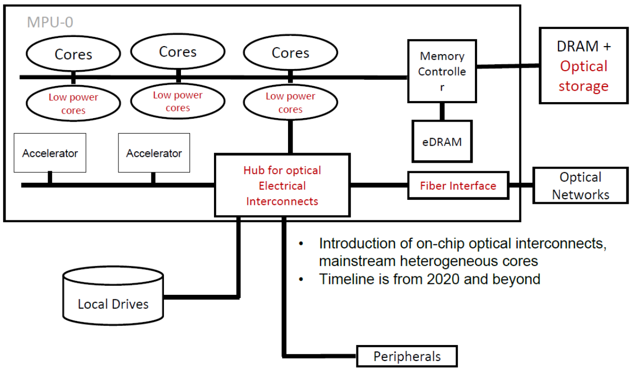

Figure 4: Microserver architecture predicted beyond 2020 [5]

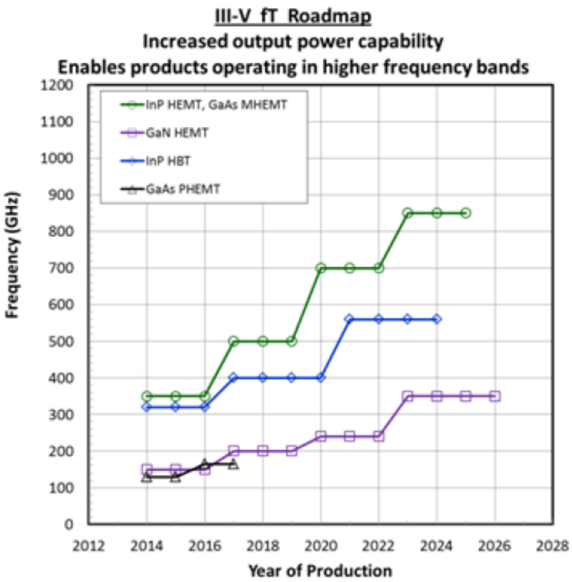

Figure 5: Roadmap for frequency requirements until the production year 2028 [3]

1) RF, Analog and mixed signals: The goal here is to develop solutions for challenges involved in device level communication, control, sensing and monitoring for the upcoming and existing frequency bands. Specifically, they target 5G cellular communications on the downlink as well as the backbone network in the 6-30 GHz and the 70-80 GHz band, wireless communications and gesture control in the 60 GHz band, radar applications in 77-81 GHz, robotic and drone control and navigation and sensing, imaging and communication in the 94, 140 and 220 GHz band.

To explain the future directions, the group highlights the roadmaps for frequency, minimum noise figure and associated gain. These are shown in fig. 5, 6 and 7. An interesting thing to note here is the trend in the curves. These curves seem to show an abrupt jump every two years and then a flat behavior for the next two years. These jumps can be attributed to the fact that this group deals with device level properties associated with connectivity. It takes a finite period before existing devices reach saturation in terms of the capabilities that they provide thereby paving way for better and advanced technology to boost the device capacities.

2) Optical interconnect applications: The main objective here is to enable efficient connectivity in data centers, telecommunications, fibre optic to X (FTTX: where X could be home, office, curb, etc), automotive and aerospace. It is interesting to note that the group does not intend to focus on health care for the next few years. The reasons are not clear. The prime goal in all of these areas is to enable high speed inter-component communication. Some areas have additional demands that need to be met. For instance, automotives require optimization of the weights of the components involved while aerospace systems require additional focus on electromagnetic interference(EMI) reduction as it could hamper the communication between the system and the ground station, immunity to high temperatures and mechanical shocks involved in the system operation.

The group identifies challenges that it faces in the area of component integration packaging. Specific examples include lasers, modulators and compact waveguides. The group also provides other examples. It seems that the group has been solving some of the problem that might fall under the heterogeneous integration group. This might be due to a lack of co-ordination between these two groups.

Other challenges involve optical switching and routing and deisgn of components to enable amplification and regeneration of optical signals.

For enhancing the quality of communication, the system identifies the performance meterics that include bandwidth, power, form factor and other features required by the international technology working group (iTWGs). The group also specifies the bottleneck elements involved in improving connectivity. These lasers, input couplers, fiber, output coupler, detectors, etc.

The group has made progress in area of simulation, modelling and testing in terms of identifying the key components that need to be studied and tested. For modelling and simulation, the group believes that the main focus should be on design optimization of nanophotonic lasers, routing and plasmonic structures. For testing, the group intends to focus on optical interconnects. Broad testing areas include laser and detector test, alignment requirements, wafer level detectors and emitters, number of fibre and wavelengths invovled in photonic elements.

It is interesting to note that for simulation, modelling and testing the group intends to focus on the features associated with the physical layer (PHY). While an efficient PHY is required to enable high speed communication, the actual data exchange happens at higher layers. This implies that the performance of the system also crucially depends on layers running on top of the MAC. The bottlenecks and performance metrics in these layers seem to be entirely ignored by the group.

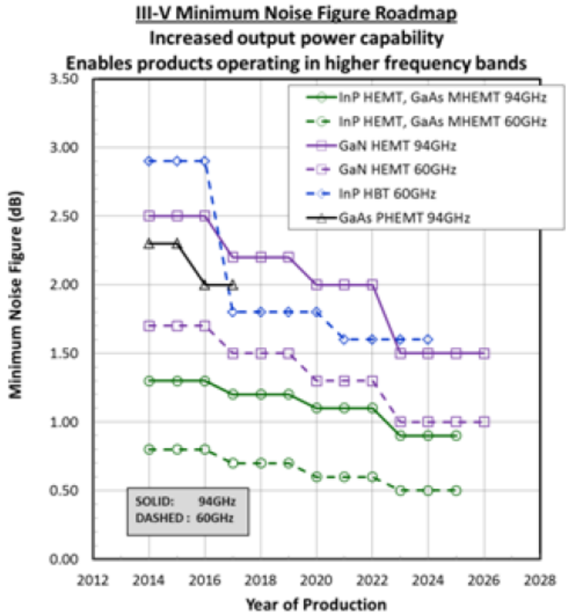

Figure 6: Roadmap for minimum noise figure requirements until the production year 2028 [3]

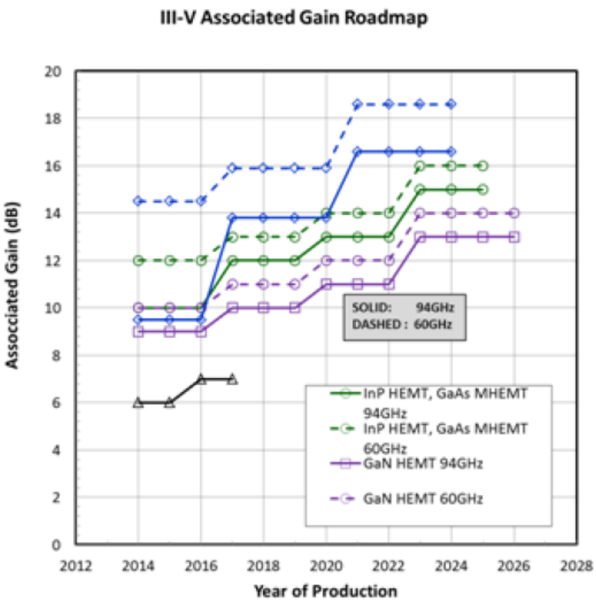

Figure 7: Roadmap for associated gain until the production year 2028 [3]

4. FACTORY INTEGRATION

The focus of this group [6] is on the tools and processes that can optimize the cost per volume of the products manufactured. The goal is to make the process of mass manufacturing of goods efficient and environmental friendly. To this end, this group has added Environmental Safety and Health (ESH) and Yield Enhancement (YE) sections to its activities. The main additions that were proposed for 2015 included those related to ESH, YI, Factory operations and security and supply chain integration. With the development of several environmental issues, the ESH addition seems a justified consideration for the future work of this group. However, it is interesting to note that the work from past years which focused on data analysis and control systems seemed to have overlooked this area.

For challenges, the group highlights that the areas of 2-D and 3-D materials and security lacks resources. Especially on the security side, it mentions the lack of expertise on team. While a significant efforts is seen in the area of data analytics, the exact role played by a factory integration group in this area is unclear. In the area of ESH, the group specifically highlights the danger of SVHC(substance of very high concern) compound lists from Taiwan and stresses the need to involve green chemistry principles in the manufacturing of materials.

5. CONCLUSION

In this paper a review of the future goals and challenges provided by the System Integration, Outside System Connectivity and the Factory Integration group of the ITRS is provided.

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