A SEMINAR REPORT ON

PROJECT ARA

Submitted By

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under the guidance of

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OCTOBER 2016

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In partial fulfillment of the requirements for the award of the degree
of
Bachelor of Technology
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C E R T I F I C A T E

This is to certify that, the seminar report titled ***PROJECT ARA*** is a bonafide record of the **CS 17L4 SEMINAR** presented by **SUDHARSHAN M** (Reg.No.12143623), Seventh Semester B. Tech. Computer Science & Engineering student, under our guidance and supervision, in partial fulfillment of the requirements for the award of the degree, **B. Tech. Computer Science & Engineering** of **Cochin University of Science & Technology**.

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ABSTRACT

In this technological era, everyone prefers to have the best product in the market. Earlier the mobile phone users were forced to spend a huge amount either to repair their phones or buy a new one to have a better performance and quality. In most cases people buy new phones just to have a better specification for a particular part of their smart phones. For some users the preference will be camera, for some it will be the battery and for some others it will be memory, screen resolution or just the design of the phone. In order to get what they need they had to buy an entirely new phone since the possibility to replace a specific part was null.

Now things have changed and the world is to witness the greatest technological advancement in the mobile phone industry. Yes, it is the invention of the modular phones. Project Ara is an initiative to make it possible to have modular phones that helps users to repair, change or upgrade the desired part by their own.

Keywords– ***Electro Permanent Magnet, Endo, Modularity, Modules, M-PHY, Parceling Scheme, Phoneblocks, Unipro***

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Chapter 1

INTRODUCTION

Project Ara is the codename for an unnamed, upcoming modular smart phone that is made of a central module board with individual modules that can be connected. The platform will include a structural frame or endoskeleton that holds smart phone modules of the owner's choice, such as a display, camera or an extra battery. It would allow users to swap out malfunctioning modules or upgrade individual modules as innovations emerge, providing longer lifetime cycles for the handset, and potentially reducing electronic waste. Project Ara smart phone is scheduled to begin pilot testing in the United States in 2016 with a target bill of materials cost of $50 for a basic grey phone[1].

The project was originally headed by the Advanced Technology and Projects team within Motorola Mobility while it was a subsidiary of Google. Although Google has since divested Motorola to Lenovo, it retained the Advanced Technology and Projects group which has since worked under the direction of the Android division. The project has since been separated from ATAP and became its own division in Google.

Project ARA develops an idea that became popular because of Phonebloks. Basically what it proposed was a new product that could be assembled by the own user. The modularity of the item would enable the user to repair, change or upgrade each module independently, instead of the whole item

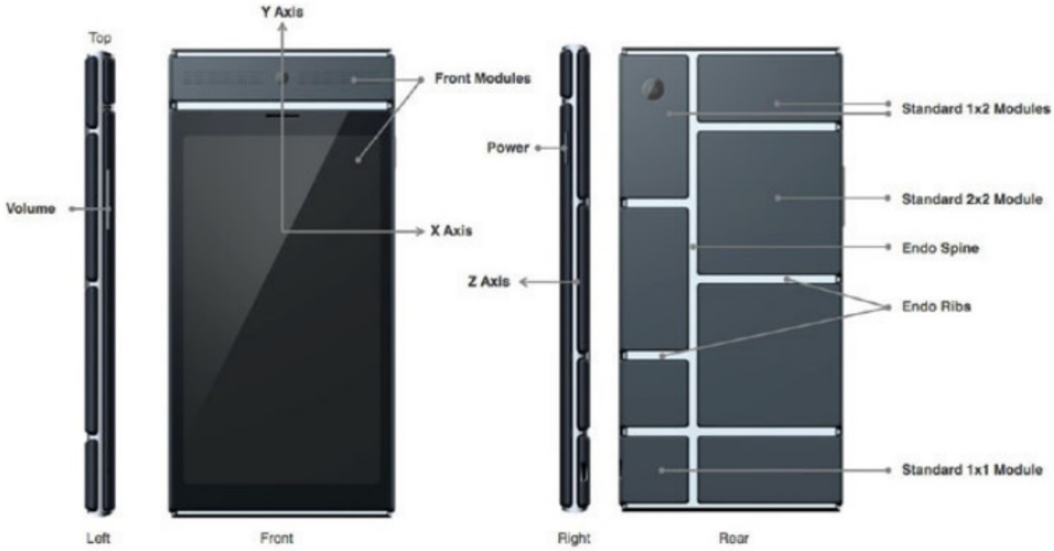

Fig. 1.1: MODULAR PHONE DESIGNED BY PROJECT ARA

Chapter 2

MODULARITY

A module is a collection of parts which are defined by some intent to be a distinct subsystem. Modules are defined by the designers, makers or users of the system for a specific intent.

The intent of the module can be:

- To make implementation easier (ease of integration, product flexibility)
- To empower the users to take advantage of the modularity to configure their own devices and optimize the operations. So users can swap the modules to make their phones to be better adapted to what they are going to do.
- To enable better services, better evolution and better upgrading of the product rather than simply disposing and throwing away the product when it doesnt meet consumers needs any longer.

2.1 STYLES OF MODULARITY

There are three fundamentally different styles of modularity.They are:

- Slot Modularity.
- Sectional Modularity
- Bus Modularity

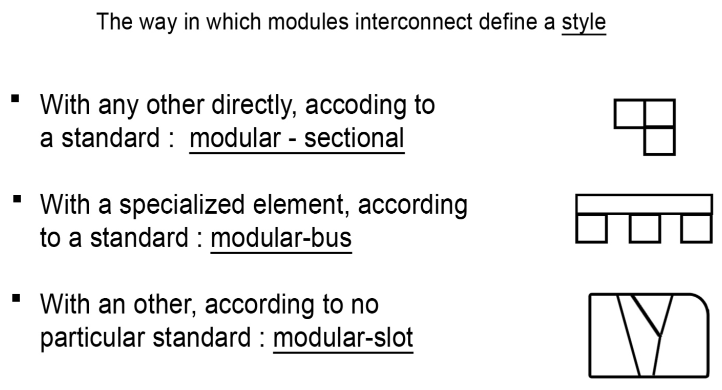

Fig. 2.1: STYLES OF MODULARITY

2.1.1 Slot Modularity

In slot modularity the modules are put together in only one very specific way and there are no particular standards for assembling the modules. If you make one mistake while assembling the modules, the system doesnt work. For example, an aircraft engine.

2.1.2 Sectional Modularity

In sectional modularity there is a specific interface standard, and every module can connect with any other module in an arbitrary ways. The classic example here is USM, a very well known modular furniture manufacturer.

2.1.3 Bus Modularity

In bus modularity the modules cant connect with each other directly, but they connect indirectly and communicate with each other through the common bus element. This is the type of modularity the Ara platform supports.

2.2 BENEFITS OF MODULARITY

Benefits of the modularity are the following:

- Greater product variety
- Module reuse and swapping
- Enabling evolution of consumers device

Chapter 3

PHONEBLOKS

Phonebloks is an open-source modular smart phone concept created and designed by the Dutch designer Dave Hakkens in 2013, primarily to reduce electronic waste[1]. While Phonebloks is not the first attempt at modular design in a phone, it is notable due to the extent of its modularity and the attention and support it has garnered. By attaching individual third-party components (called ”bloks”) to a main board, a user would create a personalized smart phone. These bloks can be replaced at will to replace a broken blok, to upgrade an existing blok, or to expand the functionality of the phone into a specific direction. Bloks would be available in Blokstore, ”an app store for hardware”, where users could buy new and used bloks as well as sell back their old ones. This leads to a longer lifespan for the other modules and reduces the waste that would have been produced if the device was treated as a whole.

There was no plan to actually produce the Phonebloks design as a commercial product, but Hakkens and the Phonebloks web site have partnered with Project Ara at Google, which aims to commercialize a different modular smartphone design[4].

Fig. 3.1: PHONEBLOKS OPEN

3.1 CONCEPTS

Phonebloks consists of a main board onto which bloks could be snapped on by the user like Lego bricks. Each blok is responsible for a unique function of the phone, much like a desktop computer has a distinct sound card, graphics card, processor, monitor, and power supply. As a result, instead of replacing the entire phone when it becomes obsolete or broken, one could simply replace the defective or performance-limiting part. If the consumer wants a camera that suits his or her needs better, he or she could for example swap their small generic camera blok for a larger zoom camera from a manufacturer such as Nikon or Canon instead of buying a phone with a better camera. In theory, this would lead to fewer people throwing away their phones and contributing to the ever-increasing problem of electronic waste. Smartphones based on the Phonebloks system would be sold part by part, as well as in starter sets. When assembled, the phone would have a screen covering the entirety of the front, volume buttons and headphone jacks along the outer edge, and bloks clicked into the back, forming a rectangular block shape overall.

3.2 TECHNICAL BARRIERS

Because all bloks are external of the main board, signals have significantly farther to travel between components. This extra distance could lead to noticeable delays between components. In addition, the quality of connection needed would require expensive pins and sockets, and developing a system to allow the user to arbitrarily place bloks would be very difficult. The end product would likely be much thicker than today's smartphones, and bloks would be at risk of dislodging from the main board. RF design of a modular phone is also a major challenge. Antennas integrated into the main body of the phone would require RF routing to the RF modem(s) in the modules and could limit the frequencies on which the phone could operate, necessitating different phones for different networks. Antennas integrated into modules could be less efficient due to limited space and EM interactions with adjacent modules, limiting range.

3.3 ECONOMIC FEASIBILITY & INCREASE OF E-WASTE

One challenge this concept faces is the great amount of money and manufacturing required in order to make the Phonebloks system a viable competitor with other major smart phone developers. Without many manufacturers making bloks, there would be a limited selection of bloks to choose from, taking away from the open-source appeal of the system.

It is argued that, if put into practice, the concept could actually increase e-waste output. They argue that by producing constantly better components, the consumer would have more pressure on them to replace several parts every few months; frequent replacement of bloks could add up to more waste on average than getting a new phone every two years.

Chapter 4

PROJECT ARA

4.1 STRUCTURE & FEATURES

Ara Smartphones are built using modules inserted into metal endoskeletal frames known as ”endos”. The frame will be the only component in an Ara Smartphone made by Google. It acts as the switch to the on-device network linking all the modules together. Two frame sizes will be available at first: ”mini”, a frame about the size of a Nokia 3310 and ”medium”, about the size of a LG Nexus 5. In the future, a ”large” frame about the size of a Samsung Galaxy Note 3 will be available. Frames have slots on the front for the display and other modules. On the back are additional slots for modules. Each frame is expected to cost around US $15. The data from the modules can be transferred at up to 10 gigabits/sec per connection. The 22 modules have two connections and will allow up to 20 gigabits/sec. This is to defer its obsolescence as long as possible.

Modules can provide common smartphone features, such as cameras and speakers, but can also provide more specialized features, such as medical devices, receipt printers, laser pointers, pico projectors, night vision sensors, or game controller buttons. Each slot on the frame will accept any module of the correct size. The front slots are of various heights and take up the whole width of the frame. The rear slots come in standard sizes of 11, 12 and 22. Modules can be hot-swapped without turning the phone off. The frame also includes a small backup battery so the main battery can be hot-swapped. Modules were originally to be secured with electropermanent magnets, but according to the team a new, better solution has

Frame	Size	Rear module slots
Mini	118 × 45 × 9.7 mm (4.65 × 1.77 × 0.38 in)	2 × 5
Medium	141 × 68 × 9.7 mm (5.55 × 2.68 × 0.38 in)	3 × 6
Large	164 × 91 × 9.7 mm (6.46 × 3.58 × 0.38 in)	4 × 7

Fig. 4.1: FRAME SIZE

been developed. The enclosures of the modules were planned to be 3D-printed, but due to the lack of development in the technology Google opted instead for a customizable molded case.

Modules will be available both at an official Google store and at third-party stores. Ara Smartphones will only accept official modules by default, but users can change a software setting to enable unofficial modules. This is similar to how Android handles app installations.

4.2 DEVELOPMENT

The first version of the developer's kit relies on a prototype implementation of the Ara on-device network using the MIPI UniPro protocol implemented on FPGA and running over an LVDS physical layer with modules connecting via retractable pins. Subsequent versions will soon be built around a much more efficient and higher performance ASIC implementation of UniPro, running over a capacitive M-PHY physical layer. A near-working prototype of an Ara smartphone was presented at Google I/O 2014; however, the device froze on the boot screen and failed to boot completely.

Chapter 5

OPPONENTS OF GOOGLE

As google has put in much interest in the field of modular phones, other companies also started working from their part. Major companies doing work on this are ZTE, Xiaomi and Bloks. We need to wait till the official release of the modular phones to know which company is going to produce the best in the field.

5.1 ECO-MOBIUS

ZTE designed a freely assembled and upgraded modular phone called ECO-MOBIUS. The phone is divided into four independent modules: LCD, core, camera, and battery. The LCD module includes the screen and lens; the core module consists of a removable CPU, GPU, ROM and RAM and other electronic parts[6]. The four modules can be easily disassembled and assembled through a sliding track design. In the ECO-MOBIUS series, main components are designed to be easily accessed and removed to make upgrading smooth, inexpensive and less wasteful. The CPU, GPU, RAM, ROM, camera, battery and display all fit within a modular framework that has a standard design across the whole ECO-MOBIUS series.

A game fanatic wants a fast CPU to smoothly run a new game. You can go to the trading platform by tapping an app and choosing to change a CPU. The system promptly finds a list of users who are selling a faster CPU. You only need to select one and buy it. At the same time, you can sell your old CPU to another user. In this way, a CPU is used again and again until it doesnt work. Other components can be recycled in this way.

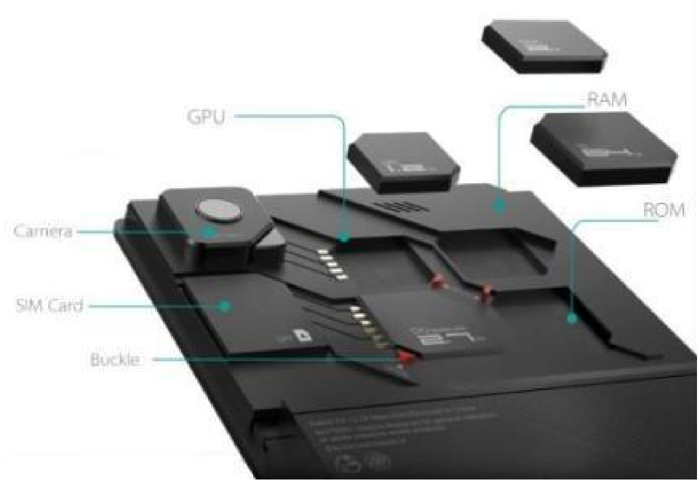

Fig. 5.1: ECO-MOBIUS

A photography enthusiast can carry multiple camera modules with them. These modules cater for different shooting conditions and include landscape, macro, or movement shooting.A traveler can overlap one or more batteries directly on the original battery module to ensure sufficient power during a trip.

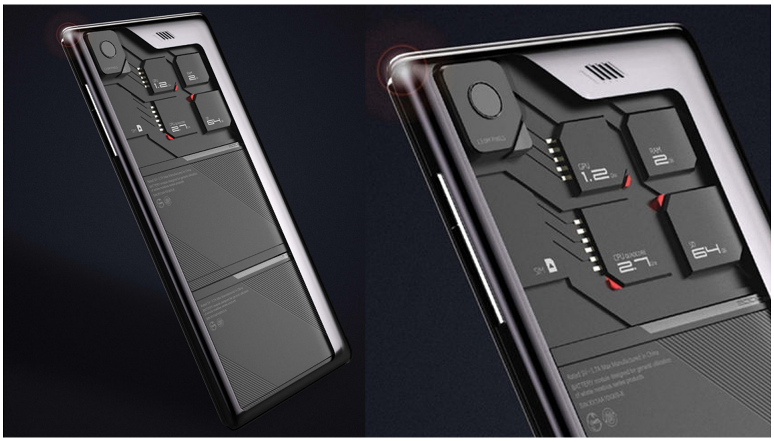

Fig. 5.2: ECO-MOBIUS DEEP LOOK

ECO-MOBIUS allows people to customize or upgrade their mobile phones more cheaply. More importantly, it is a highly efficient component exchange mechanism, making the most of materials and reducing waste.

5.2 BLOCKS: THE MODULAR SMARTWATCH

Blocks is a modular device; but rather than another phone, its a smartwatch. At launch, you'll have six modules to choose from: a GPS unit, an extra battery, a pulse sensor, a humidity/temperature/altitude sensor, a programmable button and a flashlight[7]. Blocks says add-ons for body temperature, perspiration, fingerprint authentication and gesture control are in the works. Since the platform is open, third-party developers can make more parts as well.

Fig. 5.3: BLOCKS SMARTWATCH

Each Blocks purchase comes with a watch face unit, called a ”Core,” along with four modules that form the strap; larger-wristed folks can go up to five links. The tech included are:

- A round color touchscreen display
- Wi-Fi and Bluetooth
- A microphone for voice controls
- A battery that should last 1.5 days
- Sensors for activity tracking

The watch is expected to be powered by a Snapdragon 400 processor chipset, while various modules will utilize low-power ARM chips, a clever way to manage power consumption. Blocks will run Android, but unlike most watches, it wont be running Android Wear. Instead, the watch will run Android Lollipop, which is an interesting decision to say the least, though the company has its reasons.

Blocks takes a base watch unit and allows users to add various modules as they see fit to create their vision of the perfect watch. Modules could offer enhanced battery life, fingerprint sensors, heart rate monitors, and more.

5.3 MAGIC CUBE - XIAOMI

Xiaomi Magic Cube adopts 5cm square design, which is different from the traditional controller to support 6 movements and control your smart home appliance. There are three advantages that make us love it at first. First, it plays more fun for 6 kinds of movements to shake, jog, rotate like 90 degree, 180 degree, tap double . Second, this will be the first Cube to control your home appliance smartly to make your life more convenient and easier. Third, it seems very cute and tiny, but it is so powerful for the smart function and technology. These kind of features enable us to think wildly.

Basically, Xiaomi Mi Cube will function as a standard remote control, the edges of this cube each measuring only 5cm. All Xiaomi smart home devices can thereby be controlled(like lamps, TV sets, Air Purifier etc.). This new device is capable of supporting several actions that will allow you to control a variety of smart home products from xiaomi.

The Xiaomi Magic Cube comes in three colors gray, white and gold, and has some really compact dimensions since it is able to stay inside the palm of your hand. Measuring only 45mm x 45mm x 45mm. In particular, the Xiaomi Mi Cube allows you to control Lamps, Smart TV, Air Purifiers and other smart devices by simply shaking the Cube, moving it, rotating it 90 degrees or 180 degrees, or by making a double tap on it.

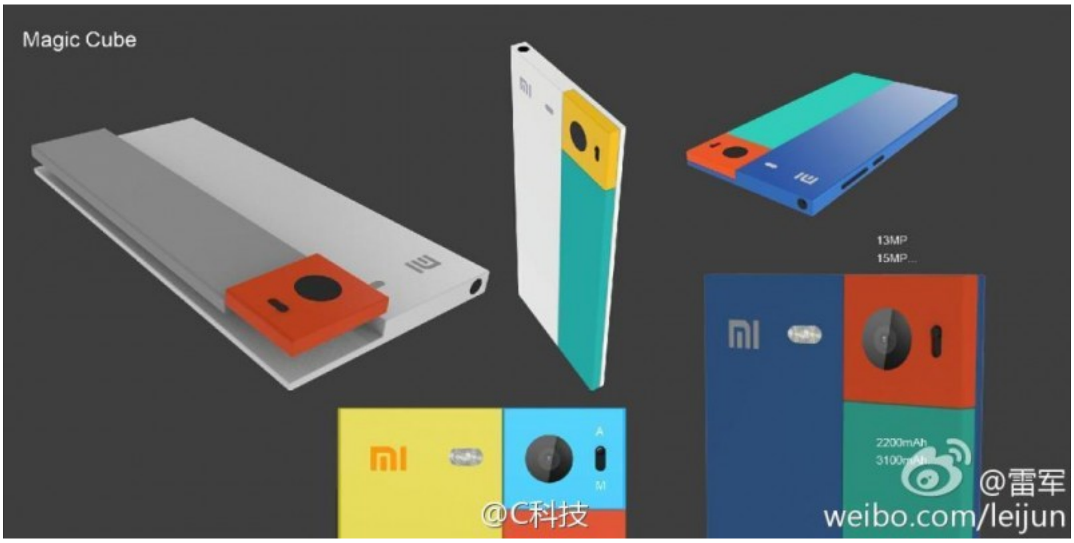

Fig. 5.4: XIAOMI MAGIC CUBE

Chapter 6

PLATFORM

The research of modular smart phones concentrated more on its implementation and platform. The basic core entities are:

- Endoskeleton
- Module

6.1 ENDO

The Ara Endoskeleton (or ”Endo”) is the frame and backplane of the device, determining the size and layout of the phone. Ara modules slide in and attach to the Endos slots, which has a backplane to electrically and logically connect modules together. There are currently three Endo size variants: Mini, Medium, and Jumbo, with varying rib configurations for each. Note that the MDK only details the specification of the Endo to the extent that it is necessary for module developers to develop modules. In the interest of maintaining the integrity of the Ara platform specification, third-party Endo development is not permitted.

The Endo, made in aluminum, is responsible only to the modules interaction with each other and to allow modules hot swapping, thanks to a small internal battery. Sim slot, memory, camera, processor, and all normal functions of the traditional smartphones will be transformed into modules. Modules will be available in 3 sizes, depending on the functions performed and will engage to the Endo by an electromagnetic system (EPM). Google will use an open communication protocol, called Mipi Unipro, to exchange data between modules to the maximum

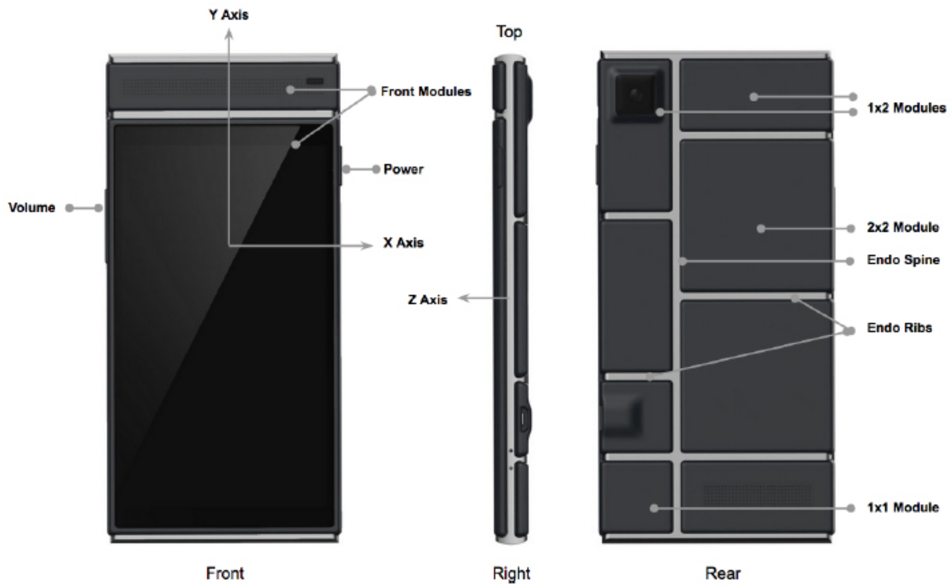

Fig. 6.1: ARA PHONE

speed of 10 Gbit/s. Will be various kinds of modules, from the traditional ones (camera, battery, processor, etc.) to those with innovative features: fitness, medical, entertainment and so on[4].

The size of this frame will regulate the amount of modules the user will be able to place in its phone. The standard size will be a 3 x 6 grid of blocks, being the block the unit size that will characterize each frame and module. In mm this is 68 x 141 x 9.7 which is similar to the size of a Nexus 5. However, two more sizes are anticipated: one smaller, called a mini Ara that will be a 2 x 5 and a Larger one that might be 4 x 7[1,5].

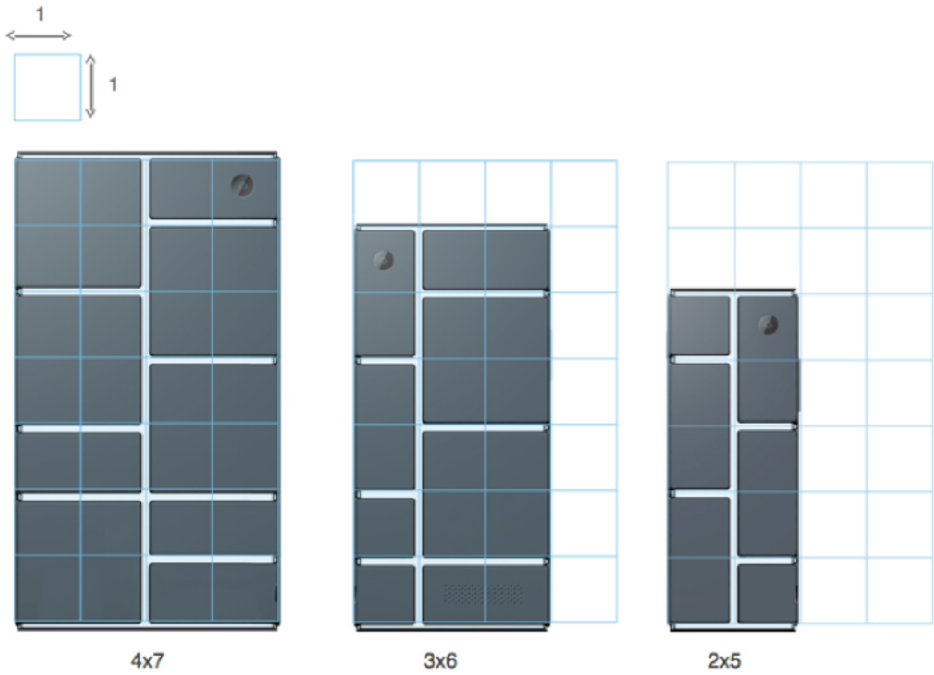

Fig. 6.2: ENDO SIZES

Endo Spine is a singular vertical feature that bisects the rear of the Endo and forms part of the module slots. Endo Ribs are horizontal features located either in the front or the rear of the Endo and forms part of the module slots.

The interface block is the area on the Endo and the modules where the electrical power pins and contactless data pads are located. The Endo contains electro-permanent magnets (EPMs) to attach and secure each module. The EPMs are activated upon module insertion and deactivated by the user with an Android application.

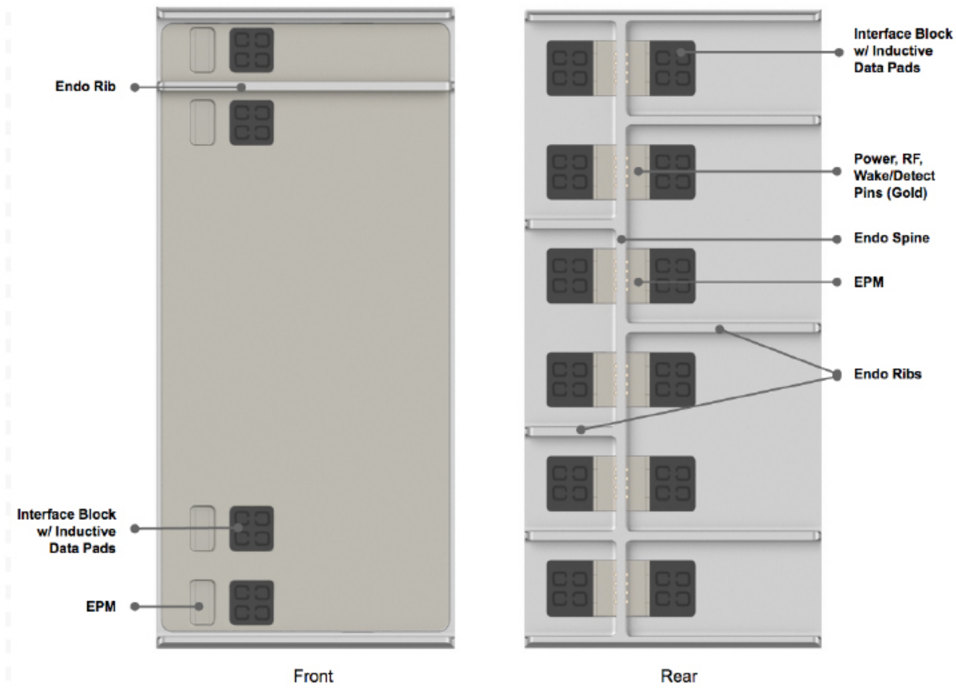

Fig. 6.3: PROJECT ARA ENDO

6.2 MODULES

All Ara phones consist of 11, 12 and 22 modules with the sizes of approximately 2222 mm, 2244 mm and 4444 mm respectively. So the length and width of the modules are strictly predefined. Big Ara phone has five 22 modules and four 12 modules. Medium Ara phone has two 22 modules, two 12 modules, two 21 modules and two 11 modules. Small Ara phone has four 21 modules and two 11 modules.

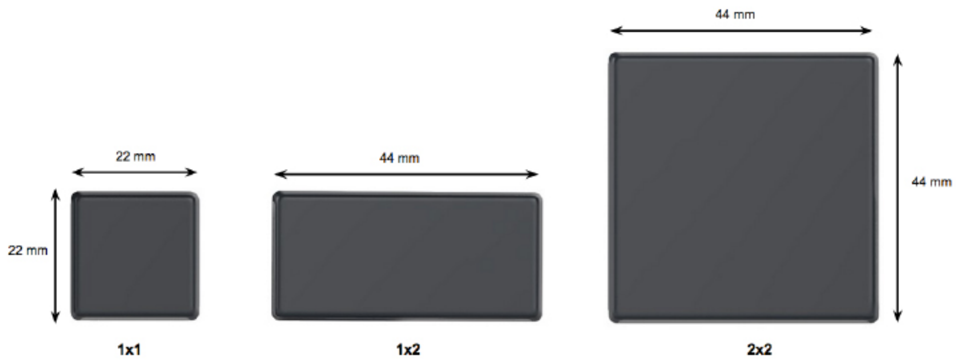

Fig. 6.4: MODULES

However, modules may have different thickness depending on module purpose and size of hardware under the module shell. For example, it might be an extra-big battery, or a module with advanced photo camera.

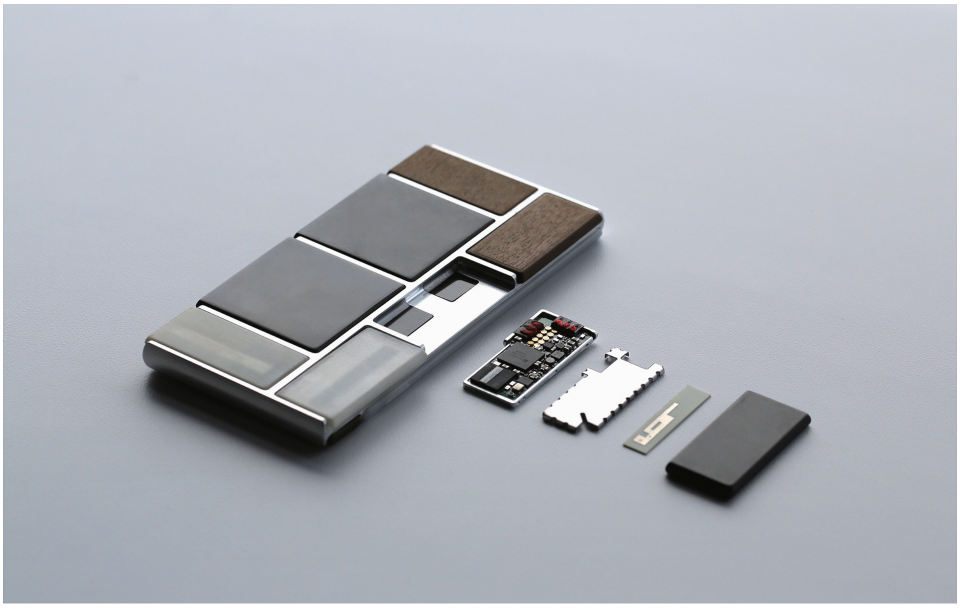

Fig. 6.5: 1x2 MODULE FOR ARA PHONE FROM INSIDE

Modules, which provide user interface (display, receiver, microphone), are attached to the front of the endo. Other functional modules, like camera, processor, battery, Wi-Fi, Bluetooth, NFC, etc. are attached to the rear side of the endo.

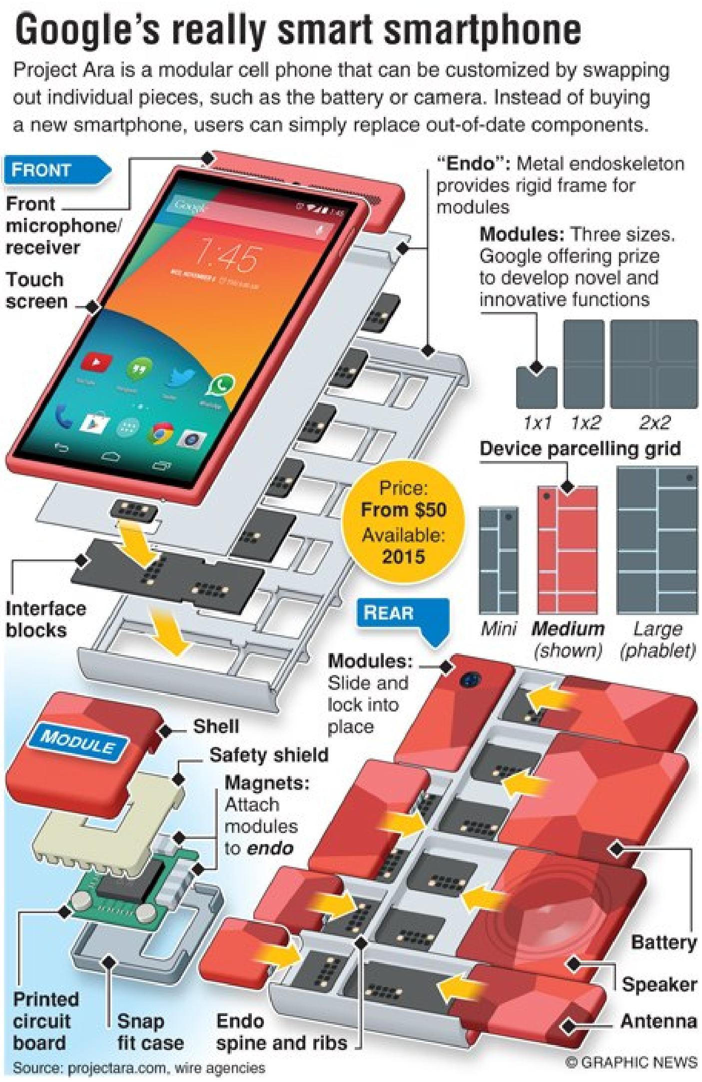

Fig. 6.6: PROJECT ARA EXPLAINED

Chapter 7

ISSUES

Developing modular devices is particularly challenging, because of issues with size, performance and price.

Here are the top reasons why it's so difficult to develop smartphones that let users swap out the processor, camera and storage options:

- **ARCHITECTURE**
  - The biggest technical challenge to building a modular smartphone is the underlying architecture, the structural frame and data backbone of the device, which makes it possible for all the modules to communicate with each other. It has to be so efficient that the overall performance doesn't take a hit and still be cheap and frugal with power consumption.
- **DURABILITY**
  - Keeping the modules in place is a challenge.
  - It also remains to be seen how the modules and connectors will be able to handle the wear-and-tear of long-term daily use.
- **PARADOX OF CHOICE**
  - If the number of options to user is small then the user will not be satisfied with the diversity.

  - If the options number is big, the user might feel overwhelmed.
  - Possible solutions to this situation are: ”Phone Makers”, that show the options according to the user’s previous choices or ask some questions in order to build the customers profile and offer an initial point.

- **FORM FACTOR**
  - Smartphones have become more svelte thanks to tighter integration between components, so the addition of chassis that needs to be quite sturdy adds to the overall size and weight.
  - Vendors have to find the best possible balance between durability and size, which won’t be easy.
  - Possible solutions to this situation are: ”Phone Makers”, that show the options according to the user’s previous choices or ask some questions in order to build the customers profile and offer an initial point.

- **BATTERY LIFE**
  - The communication between the modules uses more power than in a traditional smartphone. What the eventual power tax will be remains to be seen. It’s one of the things Google’s Project Ara team is working to improve.

- **SECURITY OF DATA**
  - In the case of memory modules, this issue is of most importance since the modules can be exchanged and used in different endoskeletons. User’s data needs to be protected in case of theft.

- **TESTING**
  - The testing part of the development process is more complicated and time-consuming for modular phones.

- Instead of having to ensure that one hardware configuration works, vendors have to make sure that all permutations work equally well.

- **CERTIFICATION**

  - MDK specifies the requirements, and module developers could either test for compliance in-house if you have the equipment, and you can actually validate the protocols or spec requirements, or you could use the services of the third party. For the measurements that the FCC requires or carriers require the accredited certification labs that you could use in order to measure compliance

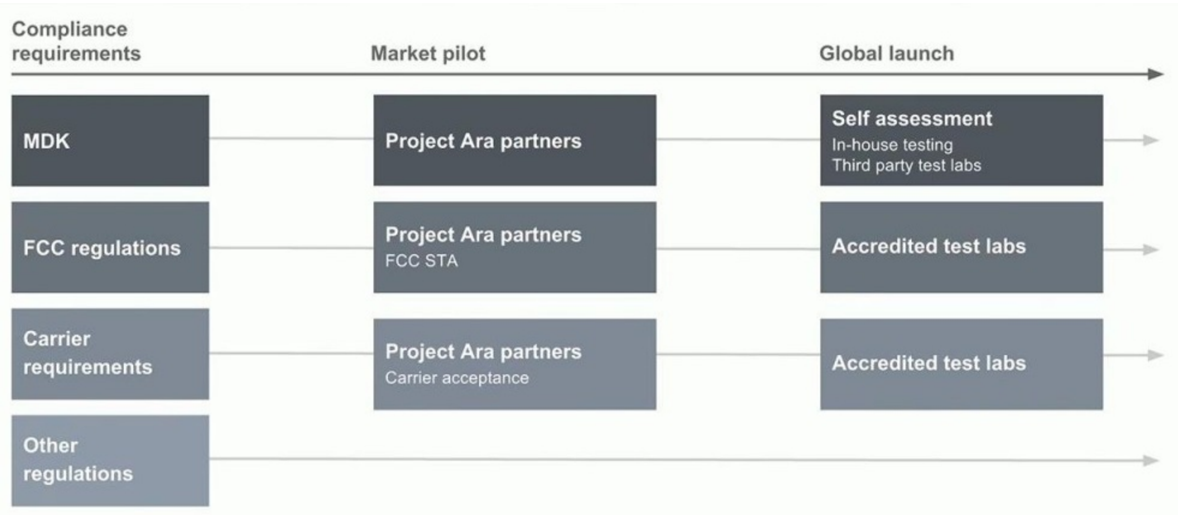

Table 7.1: CERTIFICATION PROCESS

- **PRICE**

  - A more complicated development process and less product integration will have an effect on pricing, as well.
  - The Project Ara FAQ states that its much too early to tell what phones will cost, but the bill-of-materials cost of a basic, entry-level Ara device is in the $50 to $100 range.

Chapter 8

NEW TECHNOLOGIES

There are various works under progress and the major technological developments in the Project Ara are:

- Unipro
- M-PHY
- Electro Permanent Magnet

8.1 UNIPRO

UniPro (or Unified Protocol) is a high-speed interface technology for interconnecting integrated circuits in mobile and mobile-influenced electronics. The various versions of the UniPro protocol are created within the MIPI Alliance (Mobile Industry Processor Interface Alliance), an organization that defines specifications targeting mobile and mobile-influenced applications[9]. The UniPro technology and associated physical layers aim to provide high-speed data communication (gigabits/second), low-power operation (low swing signaling, standby modes), low pin count (serial signaling, multiplexing), small silicon area (small packet sizes), data reliability (differential signaling, error recovery) and robustness (proven networking concepts, including congestion management).

From high level, UniPro is very easy to use, it is very mobile-friendly. There is a variety of other protocols that are built on UniPro. And Project Ara team is building a variety of their own protocols. Two established ones are also defined by the standards body of the UniPro: CSI-3 (Camera Serial Interface) and UFS (Universal Flash Storage) protocols. CSI-3 is a stack on top of UniPro, which transmits camera data and controls signals through UniPro network. UFS is a flash-storage standard.

The main takeaway message about UniPro is that it provides bi-directional connections for the data transfer. At the heart of the phone there is a switch that allows to create connections between modules. It's possible to have zero, one, or more connections between any pair of modules.

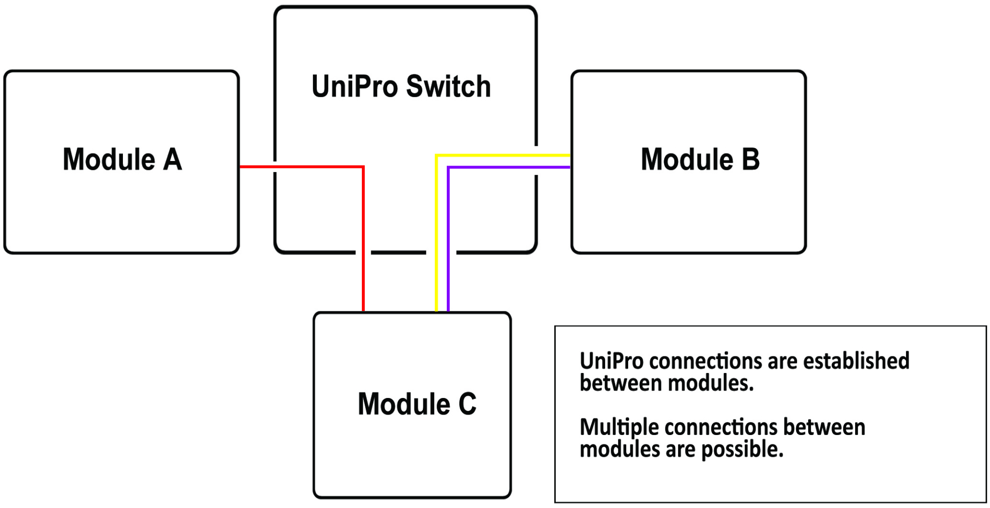

Fig. 8.1: UNIPRO- BIDIRECTIONAL CONNECTIONS

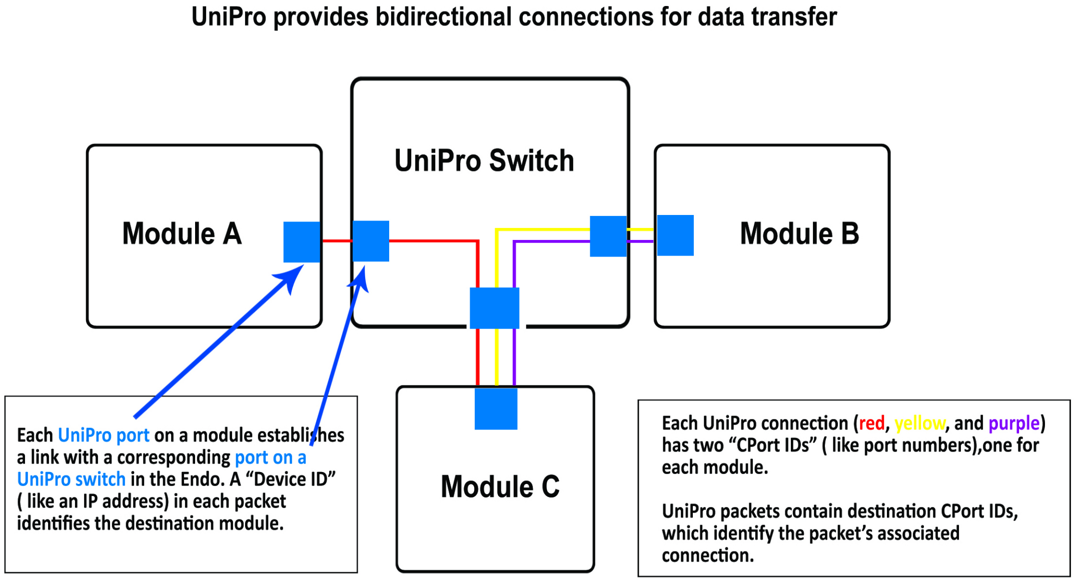

Fig. 8.2: UNIPRO- BIDIRECTIONAL CONNECTIONS

In terms of logical structure UniPro is very strictly layered according OSI (Open Systems Interconnection) seven layer model. The scope of UniPro specification is between physical layer and transport layer. The transport layer is where the bi-directional datagrams are sent and received. CSI-3 and UFS are application-specific protocols that are built on the top of UniPro,

Layer #		Layer Name	Functionality	Data Unit Name
LA		Application	Payload and Transaction Semantics	Message
DME	Layer 4	Transport	Ports, multiplexing and flow-control	Segment
	Layer 3	Network	Addressing, Routing	Packet
	Layer 2	Data Link	Single hop reliability, and priority based arbitration	Frame
	Layer 1.5	PHY adapter	Physical layer abstraction and multi-lane support	UniPro symbol
Layer 1		Physical Layer	Signaling, clocking, line encoding, power modes	PHY symbol

Table 8.1: UNIPRO- OSI LAYERING

as was mentioned already. But there is a need of a lot more of protocols. Project Ara team is working on that.

8.1.1 Features of Unipro

- Multiple independent bidirectional connections between endpoints.
- Reliable,in order transmission and reception of datagrams.
- Error Handling.
- Credit-based flow control.
- Traffic prioritization

8.1.2 Greybus - An application layer for Unipro

Greybus communication defines how modules communicate over the UniPro network. Although UniPro offers reliable transfer of data frames between interfaces, it is necessary to build a protocol that provides semantics to the data being transferred. This allows the sender to confirm that the information or instructions in the message had the expected result. For example, a request sent to a UniPro switch controller requesting a reconfiguration of the routing table could fail, and proceeding as if a failure had not occurred in this case leads to undefined behavior. Similarly, the AP Module likely needs to retrieve information from other modules. This requires that a message that is requesting information should be paired with a returned message containing the information requested.

For this reason, Project Ara performs communication between the modules using Greybus Operations. A Greybus Operation defines an activity (such as a data transfer) initiated in one module that is implemented (or executed) by another. The particular activity performed is defined by the operations type. An operation is implemented by a pair of messages one containing a request, and the other containing a response. Both messages contain a simple header that includes the type of the operation and size of the message. In addition, each operation has a unique ID, and both messages in an operation contain this value so that a response can be associated with its matching request. Finally, all responses contain a byte in the message header to communicate the status of the operation, either success or a reason for a failure.

Greybus protocol provides:

- Device discovery and description.
- Network routing and housekeeping.
- Defines class protocols, which devices use to talk to each other, and talk to the processor.

Protocols based on Greybus

There are several protocol classes based on Greybus, which are working already. Those are the battery, vibrator and NFC protocol classes. Right now there are working on more complex classes for audio, input (HID), sensors and cameras. Also there are purely tunnel protocols: CSI (Camera Serial Interface) and DSI (Display Serial Interface). The Linux kernel doesnt see these protocols at all. When somethings up to route the data, the kernel gets out of the way, the AP (application processor) doesnt care. It just works. We havent defined these protocols in Greybus specification, because the kernel doesnt see these. So there is no dont need to worry about them.

Special Protocols

This section defines two Protocols, each of which serves a special purpose in a Greybus system.

The first is the Control Protocol. Every Interface provides a Cport (Cport 0) that uses the Control Protocol. It is used by the SVC to do initial probes of interfaces at system power on. It is also used by the AP Module to notify interfaces when connections are available for them to use. A Greybus connection is established, whenever a control connection is used, but the interface is never notified that such a connection exists. Only the SVC and AP Module can send control requests. Any other interface shall only send control response messages, and such messages shall only be sent in reply to a request received at its control Cport.

The second is the SVC Protocol, which is used only between the SVC and the AP Module. The SVC provides low-level control of the UniPro network. The SVC performs almost all of its activities under the direction of the AP Module, and the SVC Protocol is used by the AP Module to exert this control. The SVC also uses this protocol to notify the AP Module of events, such as the insertion or removal of a module

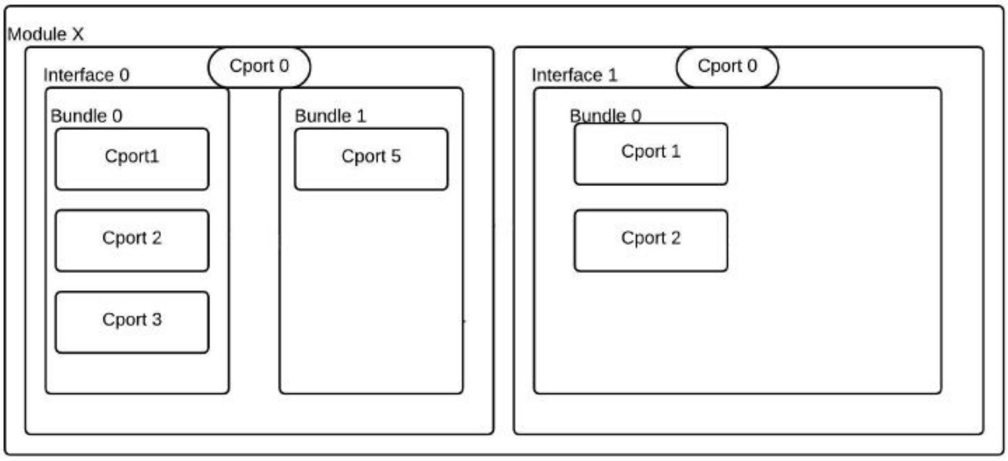

Fig. 8.3: LOGICAL PARTS OF A MODULE

8.2 M-PHY

A technology used by Project Ara. A physical layer spec also developed by the MIPI Alliance and made to work with UniPro. For Project Ara, M-PHY is a capacitive interface, which means that the connection points won't be worn down over time from swapping modules in and out of the phone. Ara's implementation of the M-PHY interface block calls for 10 connection points, eight of which are for data (four pairs of lanes), one for power, and one for ground[5].

The contactless media converter will operate over the 0.125 0.5 mm (+/- 0.05 mm) (TBD) airgap between the module and Endo. It will support all M-PHY transmission rates and modes implemented by the Ara network

The Ara network stack uses MIPI M-PHY (V3.0 26-July-2013) at Layer 1. M-PHY is a

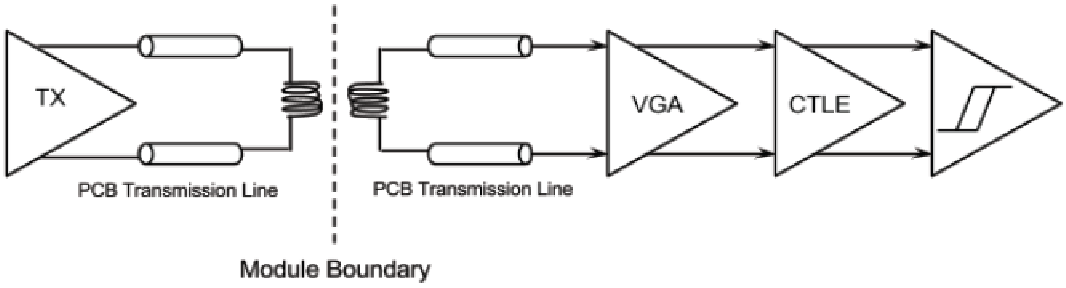

Fig. 8.4: CONTACTLESS MEDIA CONVERTER FOR M-PHY

serial interface that supports multiple transmission rates for high and low bandwidth applications. MPHY uses 8b/10b encoding and an embedded clock signal. M-PHY also has multiple power saving modes to support low power embedded devices.

M-PHY operating with the contactless media converter defined in the previous section can support up to HS-GEAR 3 (at 3A/3B Bandwidth and 4.99/5.82 Gbps per lane) and PWM-GEAR 1 to PWM-GEAR 2 (at 9/18 Mbps per lane).

Vendor	Product
Mixel	MXL-M-PHY-MIPI M-PHY 3.0 IP
Synopsys	DesignWare MIPI M-PHY 3.0 IP
Arasan	M-PHY 3.0 Analog Transceiver IP

Table 8.2: MIPI M-PHY KNOWN VENDORS

8.3 ELECTRO PERMANENT MAGNETS

The final technology in Project Ara's module design is the use of electropermanent magnets for affixing the modules in place in the Endo. This is really cool–normal electromagnets magnetize depending on if current is running through them. That would be a battery drain, but electropermanent magnets only use current to flip magnetization on and off; it's able to retain its magnetized state without draining additional power.

The EPMs provide a low-power and user-controllable method to securely attach modules to Slots in the endoskeleton. The EPM has two selectable states: the attach state and release state, corresponding to high and low levels of magnetic force. Electrical power is needed to switch between the two states only; the EPMs require no sustained electrical power to maintain either state. EPMs in the attach state provide sufficient magnetic force to secure modules into their slots on the endo throughout all nominal usage scenarios. EPMs in the release state provide a residual magnetic force to prevent modules from falling out unless the user deliberately removes the module from the endo. Users should be able to remove modules with minimal effort when the EPM is in the release state.

The 1x1 and 2x2 modules each use a single EPM. 1x2 modules use two EPMs, one for eachValid module insertion direction. Each EPM must provide a minimum holding force of 30 N in the attached state, and 3 N in the release state. This force must be applied in the insertion Direction of the module, i.e., in the X direction. The EPM attachment surfaces on the endo are made from Hiperco-50 alloy to provide enhanced magnetic holding force.

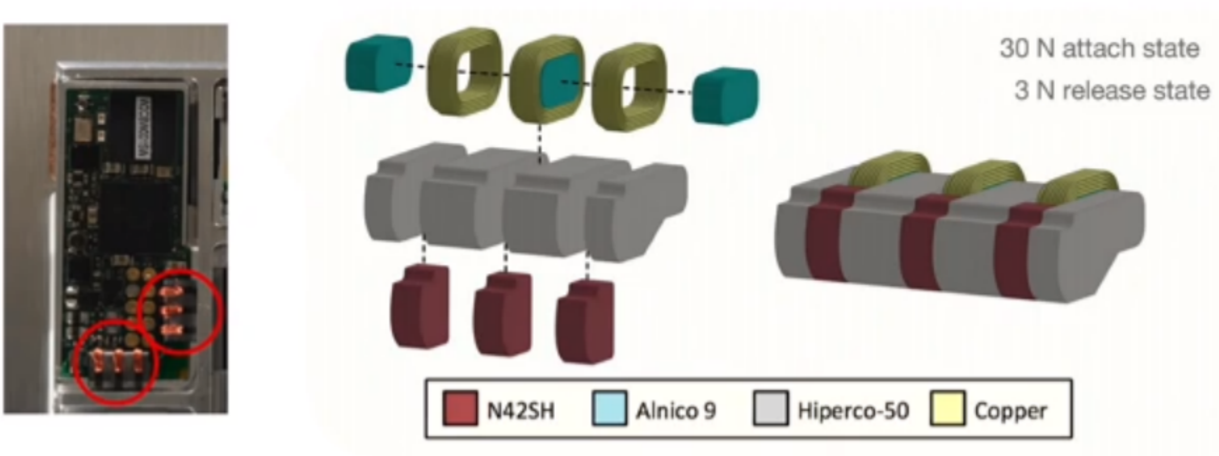

Fig. 8.5: ELECTRO PERMANENT MAGNETS

The front curved face mates with the Hiperco-50 attachment surface on the endo spine. The EPM is made from three parallel Sections. The N42SH magnets at the front are magnetized parallel to the long axis of the device, alternating magnetization direction from section to section. The Alnicomagnetsin the back can have their magnetization direction reversed by passing a current through the coils.When the Alnicomagnets are magnetized opposite to the N42SH magnets, the holding force is low; this is the release state. When the Alnico and N42SH magnets are magnetized together, the holding force is larger; this is the attach state.

Project Ara engineers are hoping that electropermanent magnet design can be further miniaturized before modules go into production, since every bit of PCB space in the module is precious. Electropermanent magnets are used to hold the modules in the endo. Electropermanent magnet has the best features of both electric and permanent magnets. Short pulse of current in positive or negative direction will turn the magnet on or off. But after that the magnet does not use any power to stay in a new stage.

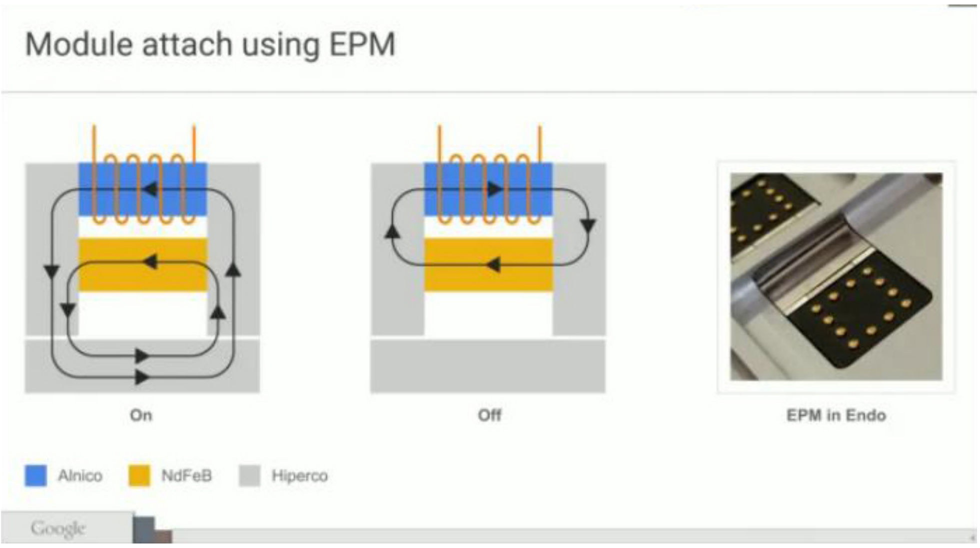

Fig. 8.6: MODULES ATTACHED USING EPM (Spiral 1)

In Spiral 1 EPM was implemented into the module.It was not implemented in the endo skeletons.

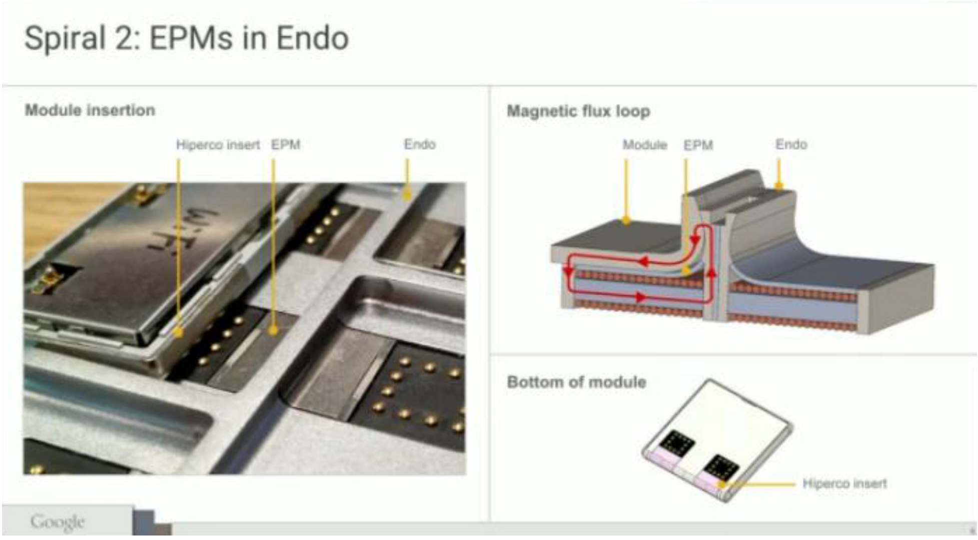

Fig. 8.7: MODULES ATTACHED USING EPM (Spiral 2)

Electrical interconnections between the module and the endo are implemented in Spiral 2 with spring pins. There are black areas with the pins on the endo which are called interface blocks. All electrical connections between module and the endo take place over those pins.

Fig. 8.8: SPRING PINS IN ENDO

Each interface block has 12 pins. 8 of them are devoted to M-PHY serial data connection. The other 4 pins remain the data bus (power and ground pin for the DC power bus, RF pin for the antenna bus, wake/detect pin which is used for power management).

Fig. 8.9: INTERFACE BLOCK

Chapter 9

PARCELING SCHEMES

Parceling schemes are rules that determine how and where modules can be placed in the endoframe. The two types of parceling schemes are:

- Front Parceling Scheme.
- Rear Parceling Scheme

The front parceling scheme only has a few possible layouts, while the rear parceling scheme can have many different configurations depending on the location of the ribs and spine.

9.1 REAR PARCELING SCHEME

The rear of the endo is parceled into 1x1 unit squares. Each 1x1 square is approximately 20mm. Note, however, that 1x2 and 2x2 modules are not exactly 20x40mm and 40x40mm due to the fact that the thickness of the missing rib must be accounted for to conform to the overall grid scheme. Refer to the computer-aided design (CAD) models and drawings for exact dimensions. All three endo sizes use the same rear parceling scheme.

The following design rules govern the rear parceling scheme:

- Endos must have exactly one vertical spine.
- For the horizontal ribs, there must be at least 1 rib per 2 units (since modules cannot be larger than 2x2).

- Only a single cross is allowed in an endo .

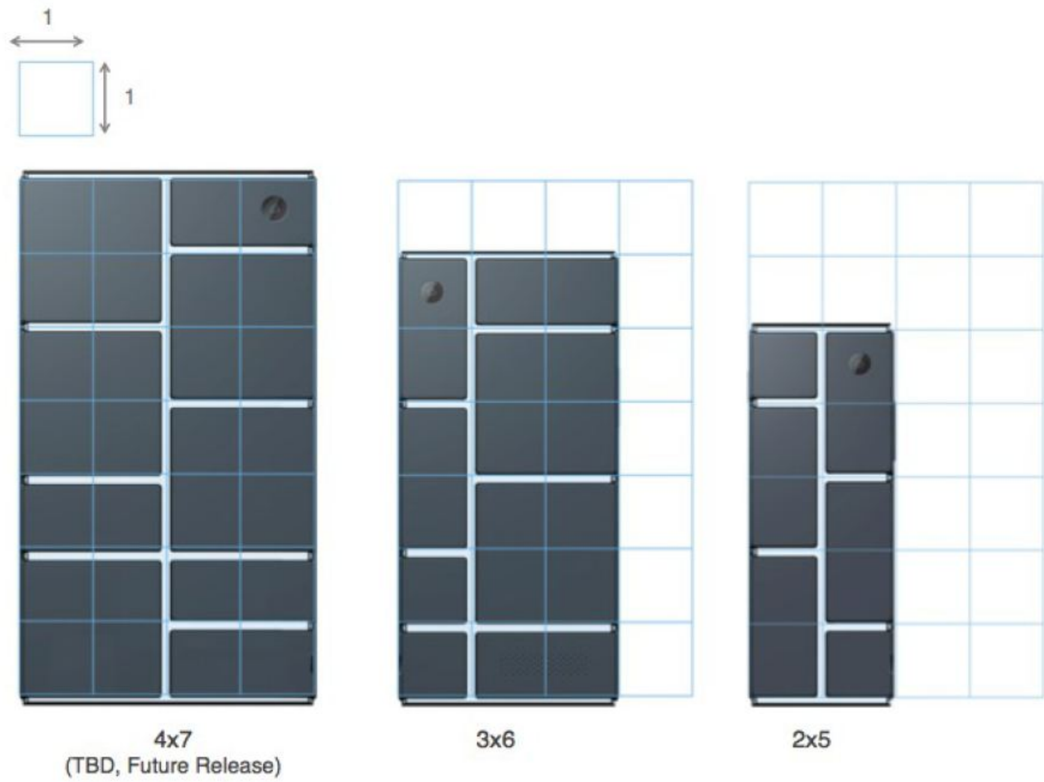

Fig. 9.1: REAR PARCELING SCHEME

9.2 FRONT PARCELING SCHEME

The following design rules govern the front parceling scheme:

- Vertical spines are not allowed - all modules must fill the complete horizontal width.
- A maximum of 2 ribs are allowed.
- Only a single rib is allowed in each of the upper or lower halves.

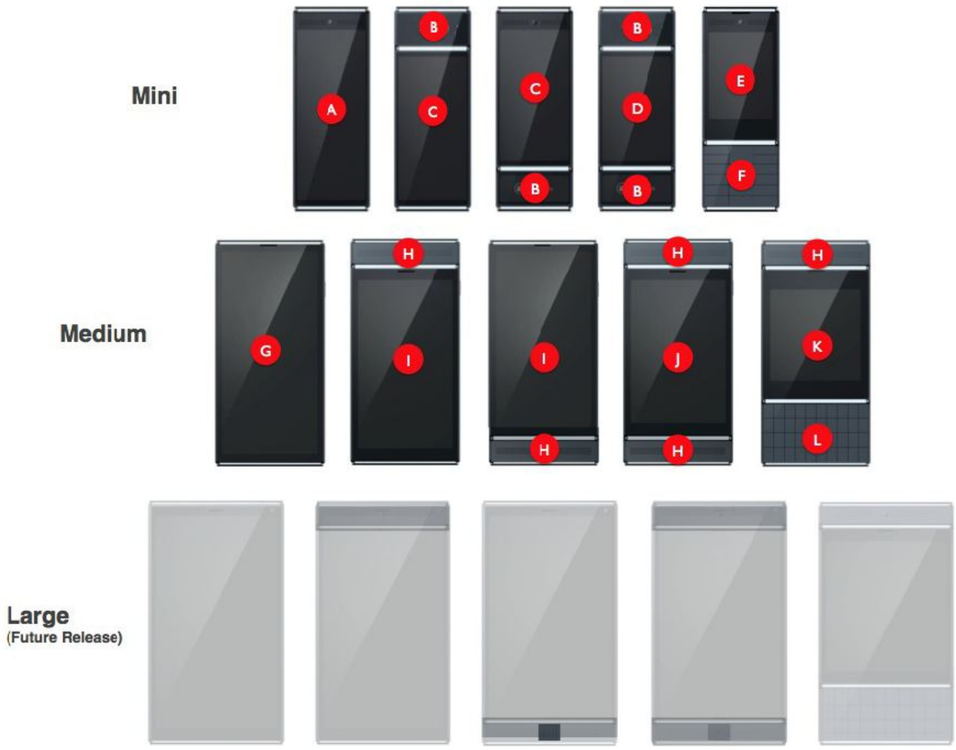

Figure 2.6 - Valid Endo Configurations (Front)

Fig. 9.2: FRONT PARCELING SCHEME

Chapter 10

SOFTWARE STACK

The Ara software stack is predicated on the attachment of a single Application Processor (AP) Module running Android. From the perspective of an Ara phones Linux kernel, there are two types of modules: those which conform to a particular device class (device classes such as cameras, displays, human interface devices, etc.), and novel (unique, or otherwise special-purpose modules) which do not belong to any device class.

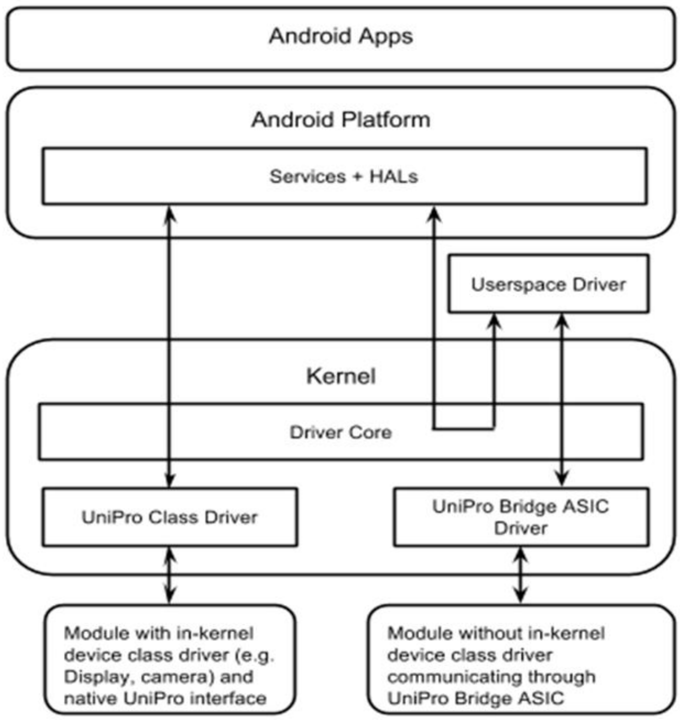

Fig. 10.1: SOFTWARE ARCHITECTURE

Devices without in-kernel device class drivers are unlikely to have native UniPro interfaces. These devices will communicate with Android through a UniPro Bridge chip driver in the kernel and a developer-supplied userspace driver.

10.1 KERNEL DRIVERS

Linux device drivers provide low-level hardware support on Android devices. On a standard smart phone, the available hardware is fixed, allowing device manufacturers to pre-select a set of device drivers. On an Ara phone, however, almost all of the hardware which is normally an immutable part of a smartphones design is designed to be user replaceable and hot pluggable. To enable hot-plug support and provide a framework that enables arbitrary future extensions, two driver classes will be developed, as previously shown in Figure 10.1 native UniPro-based class drivers and UniPro Bridge ASIC-based user mode drivers. UniPro class drivers will support a range of module devices with in-kernel device drivers that will be part of the base Ara software release. The UniPro Bridge ASIC drivers will allow a module device without native UniPro interface or in-kernel device driver to communicate with Android through the Linux driver core and a developer-supplied userspace driver. The design of this interface is influenced by the file system in Userspace (FUSE) project.

10.2 ANDROID HALS

Hardware Abstraction Libraries (HAL) are implemented as shared libraries; their code runs within Androids system services. Unlike device drivers, HAL APIs are specified by Google and are updated with each release. Device manufacturers provide library binaries which implement these interfaces in their devices system images. These libraries are then subsequently loaded by the relevant system services as part of their initialization. Among other things, HALs provide an abstraction barrier between Android system services and the various device driver interfaces exposed by the kernel for different hardware peripherals those services must control.

10.3 ANDROID APPLICATION

In general Android applications for the Ara platform are not in any significant respect different than traditional android apps. Consequently, Ara devices are anticipated to be compatible with most standard apps.

The Ara manager application is a new application that is always running and can be launched like any other Android app. This app is for the user. It enables the user in an easy way to access module information and the operations in use, and re configuring the phone.

Fig. 10.2: ARA MANAGER APPLICATION

10.3.1 Features of the Android Application

- Module lock and unlock information.
- Gauges for all available batteries.
- Cloud retrieval of module support packages.
- Help user by highlighting the issues.

Chapter 11

3-D PRINTING

Even if Project Ara doesn't work out, there's one industry that may benefit from the R&D conducted for it: 3D printing. Google is working with 3D Systems in developing a new 3D printing machine that can print efficiently at volume, something that existing printers are not very good at. 3D printing will be used for Ara phone users to customize the casings for their modules, which are user-serviceable and snap fit around the PCB and safety shield.

It will allow to choose the cover that users want. The printing system is based on an innovative process that reduces printing time. It's possible that Google realizes a store dedicated to the customization of single modules.

Fig. 11.1: 3D COVER

The 3D printer in developing will print acrylic-based plastic, similar to what Shapeways calls its Detailed Plastic material. It'll be able to print cases in CMYK color (plus clear) with detail at 600DPI, and a sub-micron surface finish[10]. The new printer, which is expected to be completed for Alpha testing mid-summer, prints using an assembly line track that goes in oval, like a racetrack. Unlike 3D printers like the MakerBot, the print head or build platform doesn't move back and forth across two axes–multiple heads and platforms work in unison, moving in just one direction to increase print efficiency.

Google is also working with Carnegie Mellon to develop conductive ink printing, so 3D printers can print electronics, like a Wi-Fi antenna while making a module casing. This technology is still a ways off, and won't make the 2015 Project Ara launch. There will also be a second Project Ara developers conference the July for artists and 3D printing companies to get involved.

Chapter 12

CONCLUSION

The Project Ara will be the future of smart phones. The platform will include a endoskeletal frame with modules of the owner's choice, such as a display, camera or an extra battery.

Since modules are interchangeable, a user has the freedom to design exactly the phone they want and continue to customize the phone over time by replacing modules. Arassuccess is predicated on a rich, vibrant, and diverse ecosystem of modules from developers. Users would be able to select modules from an online marketplace using a configurator that facilitates user choice and curates the configuration process to ensure that the selection of modules provides the expected system-level functionality

The phone itself can be swapped from malfunctioning modules or upgrades as innovations emerge, providing longer handset cycle lifetime, and potentially reducing electronic waste

It is estimated that the device is designed to be utilized by ”6 billion people”; including 1 billion current smartphone users, 5 billion feature phone users, and 1 billion future users not currently connected.

The technologies such as M-PHY, UniPro and electromagnets added a great deal to the Project Ara. They will also be advancing in its own way. The 3D printing will going to have a great impact on the future with the introduction of Project Ara.

The smart phone customization will help people save money and help to design what they really need by themselves.

GLOSSARY

- **ARM**: Advanced RISC Machine
- **ATAP**: Advanced Technology and Projects
- **CPU**: Central Processing Unit
- **FPGA**: Field-Programmable Gate Array
- **GPU**: Graphical Processing Unit
- **LVDS**: Low-Voltage Differential Signaling
- **MIPI**: Mobile Industry Processor Interface
- **RF**: Radio Frequency
- **UNIPRO**: Unified Protocol

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