Elemental Modularity Design in Smart Phones

Neelam Sharma, Nitish Pathak, Anand Kr Shukla, Vaibhav Vivek, Danish Ather

Abstract: Current statistics show that there are around 2.53 billion smartphone users on this Earth in 2018, which is predicted to rise upto 2.87 billion by 2020. Since the birth of the mobile phone in 1940s, the development in the technology was driven by technological advancements. Now, there is a factor of the social movement that partially drives the innovation in the phone technology, catering the subjective "ease of access" of maximum users. An average mobile phone user is spending around 3.1 hours per day on a phone i.e. 93 hours in a month which explains why there is a need of considering social trends along with technological innovation while designing the product. But taking everything into account, the past few innovations in the mobile phone industry were noticeably constrained to a few monotonous principles, and hence arises a need for revolution. One revolution in the software industry was initialized by the open source movement which points towards a theory for solving this tediousness in the hardware industry and paves ways for concepts like modular phones. Modularity means the degree to which a system's components can be separated and reassembled hence a modular phone is a smartphone in which different functional pieces can be swapped out. The concept promotes open sourcing movement in hardware sector and increases the complexity of the system but decreases the sophistication for the end user. This paper will demonstrate modularity as a concept, its present and future scope and an experiment-based hypothesis to create a generic modular phone based on any OS.

Keywords: Module, Cognitive artifact, MDK (Module Developer's Kit), Project Ara, PhoneBloks, Hardware Endoskeleton

I. INTRODUCTION

Creating a tool and then using that tool i.e. creating and using, these two actions define the characteristics of humans as a species at any given point of time. Two unmistakable abilities that all humans share are: first, to amend the surroundings in which they live through creation of artifacts and second, to transfer those amendments to further generations through various coded languages [1].

Digging deep into human made artifacts, Donald Norman states that "a cognitive artifact is an artificial device designed to maintain, display, or operate upon information in order to serve a representational function and that affect human cognitive performance" (Norman, 1991). One such cognitive artefact, unprecedented in its power, preponderance and the inwardness it enjoys in our personal lives, is the modern smartphone[2].

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Neelam Sharma, Maharaja Agrasen Institute of Technology (MAIT), GGSIPU, New Delhi

Dr. Nitish Pathak, BVICAM, GGSIPU, New Delhi

Dr. Anand Kr Shukla, Associate Professor, Chandigarh University, Garuhan, Mohali

Vaibhav Vivek, Maharaja Agrasen Institute of Technology (MAIT), New Delhi

Dr. Danish Ather, Teerthanker Mahaveer University (TMU), Moradabad

The modern smartphone is a result of technological advancements and changes that occurred in social trends over time. But what happens when the direction of development of an artifact constraint itself to some notions, the one solution that humans can come up with is break it all apart and then assemble it again to create a space for creativity, that is where modularity enters the technology world[3].

As explained earlier, Modularity means the degree to which a system's components can be separated and reassembled. A key misconception which needs to be clarified before any discussion is calling the smartphone family "modular". Smartphones are complex systems which involve combining various functional components to create a working architecture [4]. This concept describes all smartphones as modular, and not only smartphones it describes any complex system as modular, it may be a car engine or even a ATM machine. But explicitly calling PhoneBloks, Project Ara, LG G5 and other conceptphones, modular puts forth the implication that the smartphones of today are not precisely modular in terms of their design and are imaginably misleading the user [5].Modularity is a general set of principles for managing complexity whereby a complex system is broken into discrete pieces that communicate through a standardized interface in a standardized architecture (Langlois, 2002). This clarifies the modularity concept as even if it is a system of media components i.e. a system of image, sounds and shapes assembled to perform a collective function but they continue to maintain their own separate identities [6].

Group Technology (GT)

Group technology is the ancestor concept of modularity implemented in automated production cells. In GT, multiple machines are put in as a group to form manufacturing cells based on the standards defined for each of these conventional machines which further complement the final assembled product [7]. The process needs proper production or selection of these individual machines as synchronized group functionality during the process with minimum alterations inindividual functionality is what makes a modular product [8].

GT is implemented as Modularity in electronic products through a systematic approach, classified into four phases of the production. As each module may possess a different make hence to define the architecture of a modular product based on the phases of production process is a convenient method for each module manufacturer involved in the process [9].

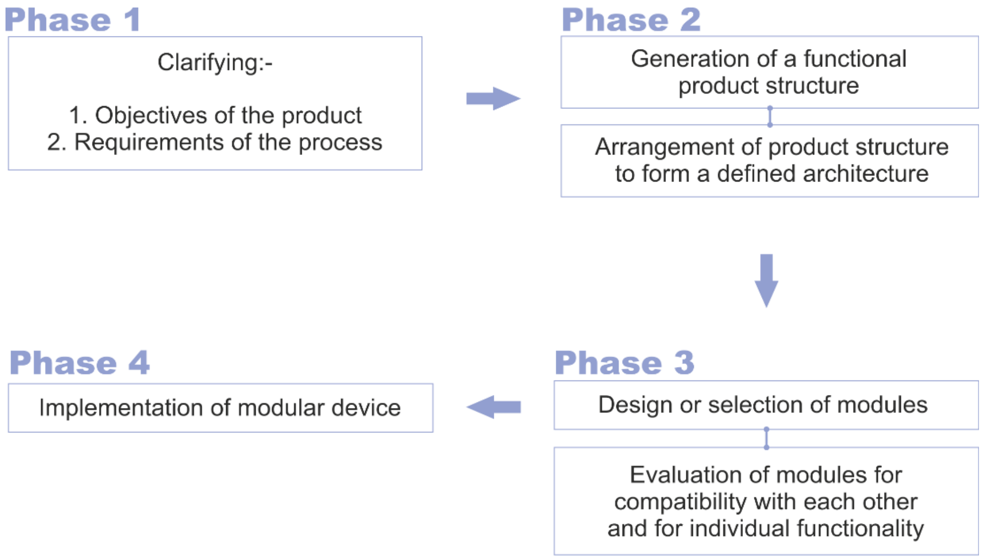

Fig. 1. Classification of the production of a modular product in four phases

The modularity production process with respect to smartphone device scan be more properly understood by studying modern day examples of modular phone devices as mentioned earlier. But when a first-generation mobile phone is considered for reconstruction through modular techniques, it is essential to reverse engineer the whole device and then move on with the goal [10].

II. DE-BLACKBOXING A PHONE

Smartphones entered the life of general public in 2007 in the name of an iPhone, when Apple announced its arrival via an advertisement named "Hello" through American Broadcasting Company, and the word smartphone is creating headlines since then. In 2008, Fujitsu released a generic structure of a smartphone in one copyrighted block diagram structure which laid the foundation for what we hold in our palm every day [11].

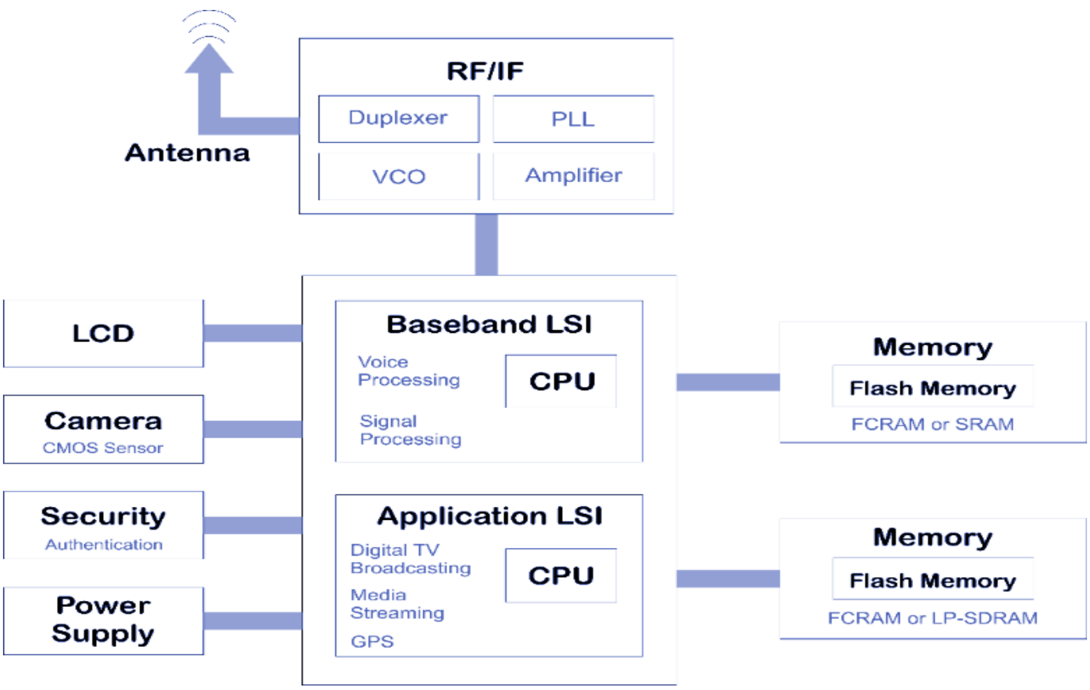

Fig. 2. Typical replica of smartphone model released by Fujitsu in 2008

The structure served its purpose and then as discussed earlier wasbranded rigid for further alterations after a given amount of practices. Now contemplating this scene through open sourcing provides the developer a ton of benefits [12].

- Decreases the total cost of ownership.
- Linus's law - Provide enough eyeballs, kill the bugs of the project.
- Reduces duplication of effort.
- Initiate modern development techniques.

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While promoting technological democracy and studying modular phones and that too in 2018, when variety of the manufacturers are producing electronic components that compatible for open source development(such the Arduino microcontroller boards), one can undeniably obtain the necessary components to develop a personalized Smartphone[13].

III. MODULES AND STANDARDS

A module is the secondary blackbox as it serves as containment for various powers (semiconductor) devices to perform a specific function. The success of a phone can be made visible by making its each module visible and all of modular phones share one common design principle: expose the module components that are currently inaccessible i.e. the screen, the speakers, the camera, the processor etc. in order to promote user satisfaction through customizations [14].

The point that need to be put on the table while separating and especially while unifying such modules is attainment of maximum compatibility i.e. software and hardware both. Compatibility among modules (likely to be produced by different manufacturers) is attained by following certain protocols and standards. The issue of standards must be elucidated before implying anything like modularity. Unless the developers, service providers and manufacturers agree onto some standards for production and interfacing of smartphones, the concept of modularity is a lost cause [15]. Project Ara by Google is however a step ahead towards accomplishment of a standard modular phone made for the open market and claims to prove as a competitor to dominating Original Equipment Manufacturers (OEMs) like Xiaomi and Samsung. Google is hoping to use the idea of creating a hardware endoskeleton as the common housing unit for the modules and Android Software as the standard OS to achieve compatibility in the device as well as traction in the market. Ara by Google is makes an attempt to eradicate the differencesamong hardware and software standards in three ways.To begin with, the hardware endoskeleton acts asa platform which acts as the connection hub binding system of modules into a cohesive whole[16]. This also assures dimensionalcompatibility since the modules must stay putto fixed sizes in order to ensure that they fit into the endo.Secondly, the MDK (module developer's kit) ascertains that thefuture designs will stick by the unified specifications Google has entrenched andhenceforth will be able to provide a communication channel to the present modules, as theymay not be manufactured by Google or any lone party developers [17].To end with, Google is backingUnipro. Unipro is a high-speed data communication protocol which would assist inovercominga part of the lost speed among the modules. Google's Project Ara's modules empower the users to customize, and essentially, unify a variety of modules befitting a distinct design. The end user's involvement in this combinational process unravels the purview for ingenuity, imagination, and therebyinstilling more creativity into the phone's construction [18][19].

Proposed example model

The implementation of a functional modular smartphone does not need to combine all of the modules at once. On a "complexity per cubic inch" scale, mobile phones are one of the most intricate devices humans use on a daily basis and while experimenting with complex modules, the process should be made as simple to understand as possible. Let us take the liberty to classify the modules into two categories: essential and special purpose modules, as per the experiment requires. The essential modules in the experimental model are:

- Microcontroller board
- GSM Interface board
- Antenna
- Keypad interface
- LCD screen
- Speaker
- Microphone

This model quite simply relates itself with the 1st generation mobile phones and not with the typical smartphones of present time. The motive to use a 1st generation phone is to reduce the complexity for the understanding of the experiment. The special purpose modules will be discussed during the further stage of the experiment. Only one special purpose module is implemented to present the concept in a lucid manner [20].The assembly is mounted around amagnetic alloy-based endoskeleton. After the essential modules are connected in the endoskeleton, it also provides vacant pins of the microcontroller board to add on special purpose modules.

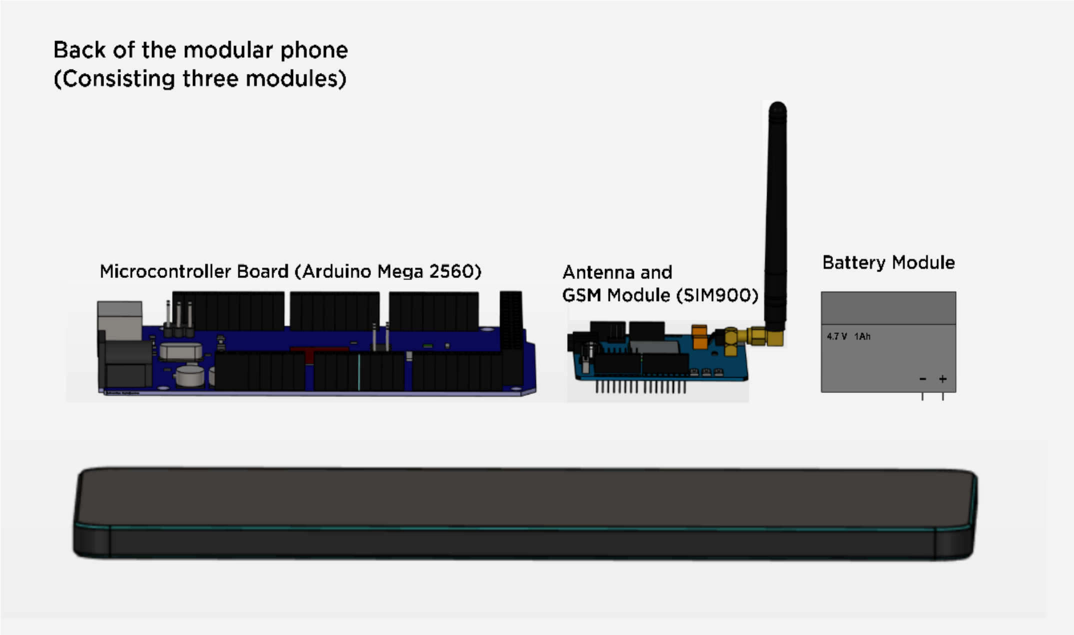

Fig. 3. Back of the proposed modular design without material housing.

The back of the phone makes space for the circuit board which has the microcontroller (Arduino Mega) and the GSM module (Sim900) connected through the magnetic plate. The power supply module or the battery (4.7 V) is also connected at the back of the phone. The housings of the individual modules are made of polycarbonate polymer (not displayed in the figure 2 and figure 3) which collectively furnish the distinctive cuboidal structure of the phone [21].

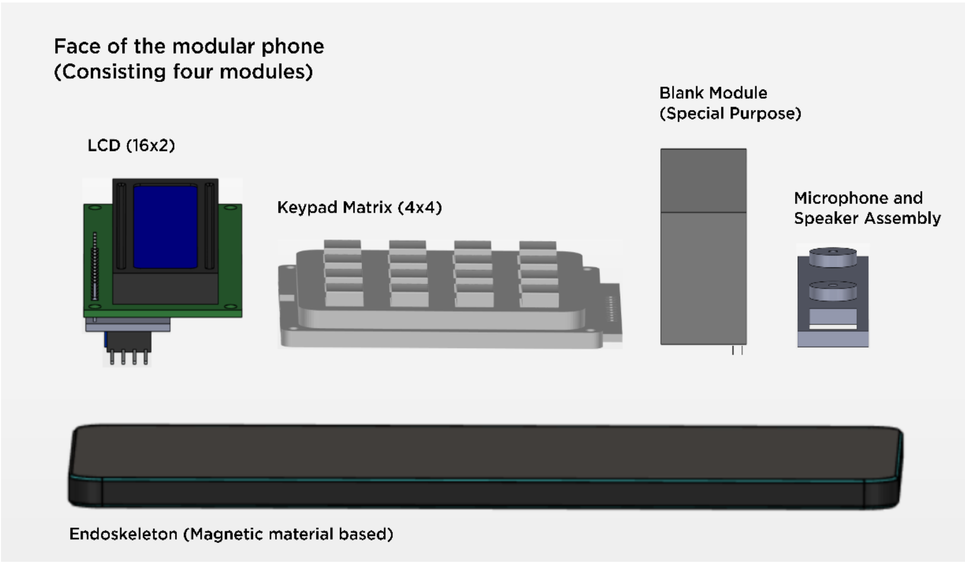

Fig. 4. Face of the proposed modular design without material housing.

The face of the endoskeleton embraces the screen (16x2LCD), the keypad (or a touch interface), the microphone and speaker mount. One blank slot for any special purpose module such as a camera module, Wi-Fi module or Bluetooth module is also made available at the face of the model.The visual description presented in Figure 2 and Figure 3 are created using the most substrate versions of the specific modules, as there is no fixed brand or make of any module, except the constraints that are put up on size and shape of the module.

Coping up with the software part is fairly simple as a lot of operating systems give more authority to developers over the code. Project Ara that is going to implement the concept of modularity through Android OS and in this experiment the OS employed is the Windows OS, as there is necessary software support available to interface such variety of modules in real time.

Interfacing each of the module through a common software platform i.e. Windows OS through a compatible compiler (here Arduino IDE) is the task that needs to be accomplished after the assembly is done. To make modularity more lucid to understand, a camera module will be implemented as the special purpose module in this model, for that an additional module i.e. memory module is necessary.

The conundrum of interfacing each module to the microcontroller chip is solved through proper choice of the microcontroller board. The

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board should have maximum number of I/O ports for optimal usage. The division of pins among the essential and special purpose modules is done, and as in the present experiment the camera module is implemented as special purpose module, hence most of the pins are occupied by essential modules. Explicitly demonstrating each module's functioning as:

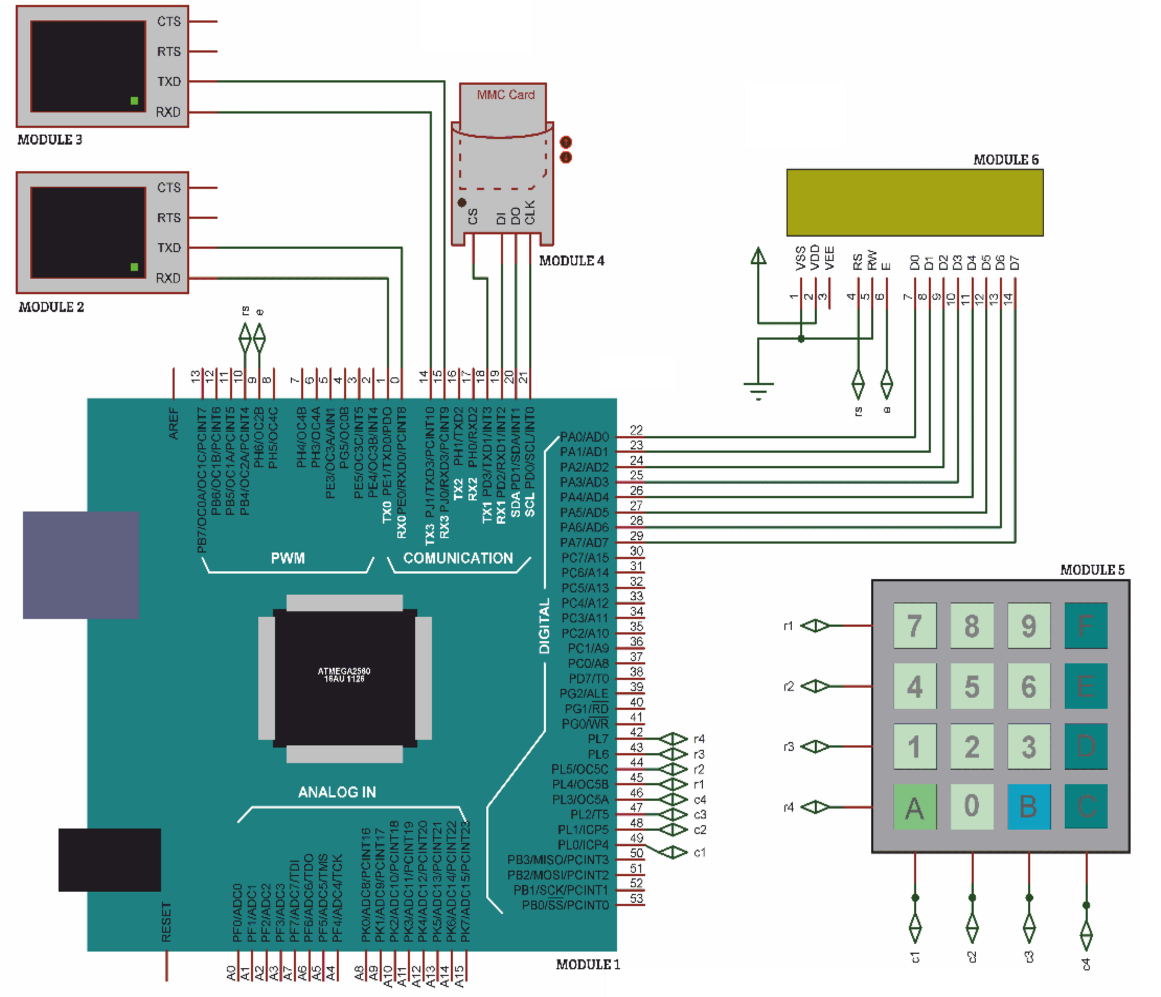

Fig. 5. Schematic of the exemplar model of modular phone

Module 1: The module with the microcontroller unit, this is a self-contained unit with peripherals, memory and processor that is used in an embedded system. Module 1 is the brain of the whole assembly; it enables communication among other modules. The microcontroller implemented here is Arduino Mega 2560 which has 54 digital input/output pins (14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. Let us assume, in our experiment 20 digital I/O pins are occupied by essential modules. That leaves us with 34 digital I/O pins and 16 analog input pins for special purpose module interfacing.

Module 2: GSM Module, represented by a Serial data interface in Figure 4. This serial data interface is occupying two pins of the microcontroller: one Tx and Rx pair i.e. one UART port for serial data communication with the GSM Module and the speaker-microphone assembly. The GSM Module employed here is SIM900A version which is a compact and reliable wireless module. The SIM900A is a complete Dual-band GSM/GPRS solution in a SMT module which can be embedded in any application. Features an industry-standard interface, the SIM900A delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax with low power consumption. Module 2 also includes the speaker and microphone assembly embedded with the SIM900A.

Module 3: This module houses one of the special purpose module of our device, the camera module and it is also represented by the serial data interface terminal occupying another UART terminal of the microcontroller. Camera module employed in the example is OV7670 camera module which is a low voltage CMOS image sensor that supplies the functionality of a single-chip VGA camera and image processor in a package capable of capturing 30 fps VGA quality. OV7670 provides full-frame, sub-sampled or windowed 8-bit images in a wide range of formats and is controlled through the Serial Camera Control Bus (SCCB) interface.

Module 4: Implementation of the camera module is not possible without the implementation of a memory module as the Mega 2560 has only 4Kb of ROM and 256Kb of flash memory. So, module 4 is an SD-Card module employed to be coupled with the camera module. It occupies four pins of the microcontroller.

Module 5: Alphanumeric Keypad module is basically a 4x4 hex matrix of switch keys interfaced through data encoding in form of 'row' and 'column' bits. The keypad occupies eight pins of the microcontroller and is a multi-press, multi-input keyboard.

Module 6: Screen Module is the final module of the assembly. The screen used here is essentially a basic 16x2 LCD Screen based on the Hitachi HD44780 LCD controller. LCD occupies ten pins of the microcontroller.

The six modules effectively form this exemplar modular phone model and aid towards the formation of a functional and substratal modular communication device. This model exclaims how easy it is to create a modular electronic device of desired specifications and that is how it promotes creativity at the root level. Each device that ensures modularity in its design arrives with a blend of personal feelings.

IV. IMPLICATIONS

This paper does not strictly comment on the viability of modularity as a concept and on the possibility of modular phones as mainstream daily devices. Arguably the most recognized advantage of modular phones in commercial market is that they reduce the electronic wastage and entitlesthe users freedom in the choice of form and functionality of they own. But it is essential to dig a little deep and discuss the aspects of thi issue in somewhat binary way.

Pros: Circular Economy

Modularity in its ideal form comes hand in hand with the circular economy, a concept which is being backed by many international organizations favoring sustainable development of the environment. The principle of circular economy basically states keeping resources in use for as long as possible and extract the maximum value from them. Then recover and regenerate products and materials in the end of product's service life for further use. For every million cell phones 35 thousand pounds of copper, 772 pounds of silver, 75 pounds of gold, and 33 pounds of palladium can be recovered while recycling and as per the statistics by Attero Blog, while we recycle 40% of our computers only 11% of our phones make it to the recycling industry and over 20,000 tons of the waste phones end up in landfills. Hence modular phones are a great way to reduce e-waste levels.

Pros: Flexibility

Currently the average lifespan of a mobile phone is about 18 months, after that phones are usually discarded because of poor functionality or for the purpose of mere upgradation. Here, modular phones provide flexibility to the user to upgrade the functionality of the device without discarding the whole device. Also, Google claims that the endoskeleton developed under Project ARAwill not cost more than $50 each. Users can upgrade their devices according to their needs and budget. Hence, modularity also provides economic flexibility to the user. It is made quite obvious above that modularity promotes creative flexibility in all its forms.

Cons: Arms Race

Retractors convey that the fuss about upgradation that has been developed around modular phones can go all against the math. As there will be more manufacturers for each type of technology of a mobile phone, the pace of innovation may increase which further states that the components are likely to get outdated much faster, which could turn the tables against the idea, as it'd result in expanding e-wastage. Another factor supporting present argument is that each component will be manufactured by a different provider with various standards in a uniform ecosystem which may lead to an arms race in the mobile phone manufacturing industry and in turn harm the environment.

Cons: Non-Uniformity

The design of modular smartphones is based on a lot of secondary assembly which results in a heavier and bulkier device as compared to the non-modular mainstream devices. Also, this non-uniformity in design can only be coped up by a certain level of technological awareness, hence there is a possibility that modular phones may only become developer toys. Non-Uniformity may also harm the performance of the phone, as such variety of optimization will be required to link varying hardware modules as well as to link software with hardware.

V. CONCLUSION

Undoubtedly, modular phone technology is another step towards evolution of the industry and it arrives with its cons. But in a world of metaphorically opaque smartphone devices, a concept to involve transparency in electronics is an initiative with great technical possibilities. This paper has introduced the outline of the aspects of modular phone technology and made an effort to simplify the term 'modularity' as it is used in reference to smartphones like PhoneBloks, Puzzle Phone, Google Ara etc. Also, the paper attempted to demonstrate the implications of modularity in smartphones: externalizing the components to enhance the creative flexibility through a basic exemplar model based on the 1st generation smartphones and that too through components that are elementary and easily available.

This discussion raises many probable ways for fruitful implementation of the concept. Universal plug-ins and standards while manufacturing modular phones can be the way to cope with the optimization issues. That conveys the importance of producer responsibility during module development process. Also, to debate with the argument of environment safety there must be proper incentives for the consumers to return and recycle the modules and not just toss them out with rest of the electronic waste.

So, if the initiatives like Google Project Ara and PhoneBloks roll out soon and fail in the competitive consumer market, it will not be a surprise as the non-modular phone market has been serving the generation since three decades and has never been disappointing in a broad sense. But if modular phones succeed to enter the mainstream market, the communication systems industry will take a revolutionizing step towards the future.

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