Digital Revolution and India

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I feel blessed to be invited to this sacred podium here and to share with yousome of the ideas that I've gathered in my career. Today we are here to discuss what is termed digital revolution, and also to review the status of India with respect to this global revolution.

The history of human civilization has passed through milestones such as Prehistoric Stone age, Bronze age, Iron age and so on. Each of them is marked with certain material inventions for the betterment of human living. After years of nomadic culture, there was agricultural revolution where civilization started settling down into settlements. In the middle ages, came the Industrial Revolution.

Industrial Revolution as of today is now marked with three stages. The first one is from 1760 to 1860, roughly 100 years and it started in Europe. The main focus was the invention and utilisation of steam powers, mechanization of various manufacturing sectors like textiles, chemicals, machine tools and so on. The second one is marked between 1870 to 1920, after Maxwell came up with the theory of electromagnetism which led to the generation of electricity. Electricity was the milestone that changed the lifestyle of all human beings mainly in urban society. Then came communication, that is telegraph, telephone and of course the means of transport such as railways and aircraft that brought the world closer and made a mark.

Digital revolution is sometimes termed the third industrial revolution. It is essentially the information era. Earlier, we had analogue devices and even computers, in which continuous signals were processed. Charles Babbage's computer, called Difference Engine, consisted of electromagnetic relays, ie, mechanical switches and gears. Later on, after the discovery of electronic valves we had digital electronic computers. The advancement of semiconductor technology ushered us from mechanical devices and analogue electronics to digital solid state device technology in the 1950s, thus ushering us into the present digital revolution.

Let us now try to illustrate the difference between analogue and digital. In nature, all signals, be it light, sound or motion are continuous. Light wave coming from a source to our eye is continuous (despite its dual nature of both wave and particle); flow of electricity through a wire is a continuous process. Analogue computers allow both input signals and output signals to have a value within a continuous range. Electromechanical relays, electromagnetic devices and then electronic amplifiers (both valve-based and transistor-based) are analogue in nature. On the other hand, when we allow only a finite number of discrete values in the computation, then it is said to be digital. The word digital is derived from *digit* which stands for fingers or toes and have been used for counting by human beings for ages. In order to simplify computing, it was modelled as a series of on/off kind of operations known as switching. As mathematicians were also working on

this matter, they showed how one could perform numerical computation much faster with digital values.

The current digital revolution is the information era that started during 1980s but before that it was boosted with the invention of transistors. Transistors were not inherent to digital computers but were found to be usable as digital switches. The first general-purpose digital computer known as the ENIAC (Electronic Numerical Integrator and Computer) came in 1946. In fact, a large number of these inventions were driven by the world war. Before ENIAC, there were a couple of other computers with limited computing ability and all these including ENIAC were made of electronic valves assigned to operate with discrete values. The three physicists who invented the transistor in Bell laboratories marked the beginning of the solid state era. The role of transistors were to replace large electronic valves by very small electronic switches. The ENIAC computer was quite space-consuming and it could not even calculate what today's hand-held calculators or smartphone apps can do. However, the size of transistors became increasingly smaller (halving every two years) and led to the invention of what we call integrated electronic circuits.

On the one hand we could actually fit in large portions of circuits in smaller and smaller dimensions, and on the other, we could build more and more powerful digital computers with these smaller transistors or electronic switches. For nearly 20 years, the scale of integration kept increasing. So we had small-scale and medium-scale integration in 1970s and by 1980s, we had very large-scale integration (VLSI) of electronic circuits. Then from 1980s we had personal computers and at the same time the notion of computer networks emerged. A computer network means connecting multiple computers to networks through electrical wires so that information could be exchanged between these. In fact, the first mobile phone also came in the 1980s.

As the hardware technology started progressing, the march of science and technology went on based on these hardware. In 1990s, we had the worldwide net which was an extension of the computer networks. Although the internet started mainly in the developed countries, by the 2000s, it spread all over the developing world and also in other domains such as digital signal processing for voice, audio, images, videos, TV signals. The internet also provided the base for telemedicine. These were some of the developments as part of the digital revolution and information era. In 2010 and beyond, the coverage of internet reached about 25% of the total world population. Mobile phone has a much wide coverage (70%). We also have tablets, smart phones, etc. Today we have driverless automobile cars, robots, 3D printing and what not—sky is the limit for imagination.

Excellent synergy

All these are possible because of an excellent synergy between computing power and telecommunication idea. This is often called Information and Communication Technology (ICT). It is based on hardware technology and software algorithms. The integrated electronic circuits find applications in camera, cell phone, TV, personal computer, sensors, wearable medical devices, etc. It is also required for exploring outer space. The integrated electronic circuits are called 'chips' because these are made from crystalline silicon. Almost everybody in modern civilization carries a chip since it is there in every mobile phone.

The chip is made from sand; there is no scarcity of sand on earth. Sand contains silicon-dioxide which is used to get silicon

crystals, known as ingots. These crystals are sliced into thin discs which are polished to make them smooth and then some patterns are created on the disc with the help of laser light. The pattern matches with the circuit. One disc is nearly 30.5 centimetre in diameter and contains many small chips. The small chips measure 2.5 cm x 2.5 cm or 3.0 cm x 3.0 cm. We have to keep in mind that there may be to the tune of one billion transistors within that little space. Now the diameter of human hair is 80 to 100 micron (10 lakh micron = 1 met). In 2017, integrated chips that are being prepared for Intel or other microprocessors are 22 nanometres in size; one thousandth part of micron is a nanometre. One can thus imagine how small these chips are. The multi-core processors are typically made up of chips and are used in computers, mobiles, fridge, TV etc. It is very interesting that integrated circuits which are used in the computers are designed with the help of computers.

Previously, computers used to be installed to occupy a large room. There used to be tape or punch card system for writing programs and then for feeding those into the appropriate readers in the computers. The next day we were to collect the output which used to show error in most of the cases and hence had to repeat the whole process. Now those are all history.

At present whatever we do all-day-long, whatever we need, most of our information requirements can be fulfilled because of this digital revolution. For any information we look up the software called Google. We type whatever we want to know into an internet-connected computer or smartphone which searches and reports on the findings. This internet is connected to a large percentage of computers worldwide. It is not that all the computers are always connected to the internet but from the connected ones, information stored in them are accessible. Connectivity is for not simply e-mail but also video-chat; e-mail is only text but through video-chat we can see the person on the other side. This video signal is converted into digital signals and is transmitted through the internet made feasible by telecommunication. The computers have certain software which function on the hardware and enables us to convert the received signal to images which we can see. But the wire carrying current has no picture in it. The current flow is also digital, either 0 or 1; 0 means negligible or no current and 1 means more current. Another advantage of digital is that the consumption of electrical energy is much less since the current is not continuously high. For this reason, a number of circuit elements can be placed in small area. Otherwise there remains a possibility of the circuits getting heated up which might eventually damage the system.

We now have faster and broader communication channels. That is another reason why sensors sense at a location and then through wireless media send the information digitally to another device where the computation can occur to produce the output. It can also have an actuator in a location, even remote from the computer, yet the computer can control the actuator such as a motor to respond to whatever was sensed by taking corresponding actions. For example, we have lot of cameras which can be controlled from a distance through some communication medium, termed as wireless. This has mainly been possible for advanced battery technology and sensor technology, and better telecommunication. It is not only due to faster and broader communication channels but also the development of many mathematical methods to improve how to send the information in a very compact manner. As mentioned before, there is integration

of electronic and micro-mechanical circuits.

Education and smart service

Digital revolution plays an important role in education. Now all the famous lectures in the renowned universities are available on internets. Thus the students can get these lectures along with the videos of the pioneers in the specific fields. This is now available to students in school level also.

We very often use the word 'smart' in technology. Earlier electronic devices were mostly stand-alone, and a human being had to activate them by turning the switch on. These were most likely programmed ahead to do certain things and there were interactive modes. But now, it is capable of those functions almost continuously. It takes inputs from either a human being, or the environment, or as various other parameters through sensors. We have advanced sensors in today's smart phones. Also most of the devices that we have now are hand-held or portable so that these can be easily carried anytime, anywhere.

Using this smart service it is possible to have e-education even at school level, e.g., virtual dissection table. Here the students, in their biology practical class, need not dissect a real frog to know about the frog system; instead they can learn everything from the computer image. They can see what are there inside a frog, which sectional view is needed to get a particular information and so on. In India we are yet to provide this service.

Today travel from one place to another anywhere in the world has become much easier. Cab or taxi booking is possible through the internet from the spot where you are. Previously we had to ask people for a route unknown to us. Now with the help of the road map and global positioning system (GPS) we are able to get the details of the route in advance.

We don't have to stand in long queues anymore in front of the railway reservation counters; we buy train tickets on-line along with confirmed reservation. Same is the case with air ticket reservation. For hotel booking also we have on-line facility. There is also provision for on-line shopping and several other types of entertainment such as music, films, games. The young generation often use their mobile phones for listening to music and watching movies. The elderly or those who live alone are also learning this user-friendly technology in order to have infotainment and shopping without having to step outdoors.

Health care

Let me next elaborate on how the Internet plays an important role in health care and telemedicine. Information related to any particular disease is readily available on the internet, hence there is no need to panic unnecessarily in the event of any unusual physical symptoms. You can also learn about the total number of patients suffering from the particular disease you are searching for. You also get information regarding the symptoms, remedy, side effects of the medicine if any and many other queries.

Health care is another benefit of digital revolution. Sometimes we find people wearing something like a watch that shows the distance you have covered, the total time you've slept, your heartbeat, your blood pressure etc. Research is already going on to find ways of measuring blood sugar without drawing blood from the body. Scientists are also working so that the health-related information can be directly conveyed to the concerned doctor. For example if the heartbeat pattern shows abnormality, the doctor might advice to be cautious, otherwise there is a chance of heart attack. Pacemaker is a fruit of digital revolution.

Another invention is the insulin pump which is placed inside the body and can be controlled wirelessly from outside by the doctor. For Parkinson's disease, some nerves in the brain that stop functioning can be activated using electronic stimulators.

Now it is possible to know exactly the 3D position of any fracture, and 3D printing can be obtained for the casts required for them. Earlier we had to wait for a long time, since the material or materials needed had to be imported. Presently the technology is available to us and with the help of 3D printing, the spare parts can be prepared. 3D printing is also used for product prototyping; this is mostly done before launching a new product in the market. This is done to check whether the product to be marketed is worth the qualities claimed. 3D printing being expensive is not affordable by all in our country.

Digital revolution has given us Smart home appliances, for example, T.V.; remote is already in use for quite long. It is also possible to give voice command (instruction) for any particular type of programme. Gesture can also be used to give command. Smart door locks and smart refrigerators have also become operative. These are needed keeping in mind the problems of the aged people who are very sick and can't even get up from the bed.

An essential part of modern life is the finances. Through net banking, one can perform banking operations without visiting the bank with the account. One can file income tax return, pay advanced taxes, pay utility bills such as for telephone and electricity bill on-line at any suitable time from your home.

Another facet related to digital revolution is the cloud service. At first, digital computers used to be very voluminous; gradually these became smaller but more efficient. However, till a few years ago, a huge amount of electrical power was imparted to the computer so that the enormous number of various activities could be completed very quickly. But with a vision for further improvement with respect to power consumption came the idea that instead of deploying a huge computational load on individual computers, we can employ a large computer placed at a distant place with the help of internet to perform those computations and return the output to us on our computer. This is called cloud computing; as if the invisible large computer is placed in the land of clouds. Thus the computers that we all are handling need not be very powerful and hence not costly. So the idea is to provide the service to all through the internet.

Smart apartment

Last year, I had been to the University of Bremen for 3 months in connection with a research programme. There I saw a smart apartment. This apartment is meant for very old persons who stay alone and can move only using a wheel chair. The apartment has a speaker fitted on the top; whatever is being spoken is taken up by the speaker and is sent to a computer through wireless. It may be a command to lift the bed (as in hospital beds); it is being lifted on its own. Suppose one wants to go to the toilet; the wheel chair reaches the person after receiving the command. The wheel chair has a motor and a sensor fitted with it. This sensor senses where and how to go avoiding obstacles. If the person enters the kitchen for food, the smart fridge informs him/her about the food stuffs kept in it; the computer had already been informed about the items which were going to be kept in the fridge. Also the type of clothes required to be worn is automatically decided once it is being informed. For example, when the person has to go to the hospital, depending on outside

temperature, the particular drawer opens up and the dress of choice can be picked up. All these are actually possible and are not just imagination. A smart home has everything smart including the smart bulb and the smart plug.

Smart cars are also evolving rapidly in this decade. All the vehicles plying on a particular road can communicate with each other. With the help of advanced sensors, these vehicles can avert any collision. A vehicle gets the idea about the position of the other vehicles and accordingly can move away. There are hundred or more chips inside each of the cars that we use normally. There can be different sensors showing, for example, how much petrol your car is left with, how many miles you have covered, etc. Earlier also we had sensors but those were mechanical (non-electronic) sensors. These are called intelligent transportation systems. They not only interact with themselves but also can look ahead. They have the map-reading facility. So they can see whether there is a traffic jam; the car itself will advise you to take a different route if you are driving. You can also have cars which don't need a driver. It is suitable for visually challenged people or elderly people who are not allowed to drive legally. One type of smart car can be driverless, in another type there can be a steering and the person in the driver seat may hold on to the steering wheel or may have hands free mode. So these are some possible scenarios which are actually there.

We already have the smart rings. The ring can act as an earphone, can act as gesture control to change the TV channel. We also have visualizers. Various things are possible now. Another technology that has been developed very recently is virtual and augmented reality. Normally, the images we can see are two-dimensional, a projection in a plane. It is now possible to see in a three-dimensional manner through a pair of special glasses in a headset. A virtual assistant is needed for all those who are not quite used to computer operations. Cortana is a voice-controlled virtual assistant for Microsoft Windows. If we just tell Cortana what we need, it will work accordingly.

All these are possible since we have so much compute power in a very small device. At the same time if we have more than one billion transistors placed within 3cm x 3cm, operating at a very high frequency as it is very small. Also we have developed ways to dissipate very low energy; so we can operate for a long time at a very high frequency to the tune of 2-3 gigahertz. So one can compute a lot within a very small time. Amazon 'echo' and 'echo dot', Apple Home pod, Google Home are some of the assistant devices through which a lot of smart devices can be connected and controlled.

Crypto currency

Next let me move onto a very interesting concept of crypto currency such as the bitcoin. Every country in this world has its own currency and if you travel from one country to another, you have to convert to the local currency with an additional charge for conversion. So there is always an overhead of changing currency. In order to overcome this problem, the concept of virtual currency in cyber-world came. Furthermore, for every financial transaction one must make sure that whenever information is being sent through the communication channel, are secured. The information sent via communication can be tapped (similar to phone tapping). These information therefore has to be encoded and only the legitimate recipient can decode and then can read the information. This process of encoding and decoding is known as cryptography. This is comparable to sending some valuables in a locked box to somebody

who has the duplicate key of the lock. When the box reaches its destination, only the recipient can open the box. If the box gets stolen on the way, the lock has to be broken for getting that valuable. So it is definite proof that the box with a broken lock is in the possession of a thief.

Crypto currency is a digital asset designed to work as a medium of exchange using cryptography to secure the transaction, to control the creation of additional units and to verify the transfer of assets. The most commonly used crypto currency is the *bitcoin*. This is a worldwide payment system and is the first decentralized digital currency. It is not controlled by a particular bank and is similar to the stock in the share market. Its value keeps changing. Yesterday (4th December), the value of 1 bitcoin was 731333.15 INR. A week ago, it was less; after one week, it may be more or less again. The value changes depending on the number of transactions. Though bitcoin is most commonly used, it has other contenders such as Ethereum, Ripple, Dash (Digital cash), Zcash etc. Digital revolution makes all these possible.

India's benefit

Let me now touch upon how much has India benefited from this digital revolution. Here the aim is to develop a secure and stable digital infrastructure. Financial transactions are not possible if they are not secure. Stable digital infrastructure is required, else the customers will face problems. Almost all of us have frequently faced the problem of 'server down' in banks. This is because we have started digitalisation but the process is not yet complete. In the above-mentioned case, the computer in a particular bank is connected to another computer in the main branch; whenever there is a lack of communication, the customers in the bank do not get the necessary information. These methods have started functioning efficiently in the developed countries. Although we are being mandated to adopt these methods, the system is not totally ready and hence we are facing a lot of problems.

India is a large country with huge population; hence government services need to be delivered digitally and of course we must have literacy (Universal Digital Literacy). As taken from the official website, the ***9 pillars of Digital India*** are

(a) Broadband Highways: This means very fast communication
(b) Universal access to mobile connectivity
(c) Public Internet Access Programme
(d) e-governance: Reforming Government through technology
(e) e-kranti: Electronic delivery of services
(f) Global information for all
(g) Electronics Manufacturing: This is an expensive proposal but we do not need 22 nanometre (nm) for all kinds of electronic devices. We can do with 90 nm or even 180 nm which are larger; that means we don't need a very big circuit for that particular device.

JAM TRINITY is the initiative from the government of India. Here 'J' stands for Jan Dhan which is e-banking, 'A' stands for Aadhar which is one identity and 'M' is for Mobile that is e-connectivity. So JAM refers to link Jan Dhan accounts, Mobile number and Aadhar cards of Indians to plug the leakages of public distribution system.

There are different digital payment methods that have come up, for example, the banking cards. Aadhar, which means 'foundation' in Hindi, is a 12 digit unique-identity number issued to all Indian residents based on their biometric and demographic data. But the problem is that biometric data do not remain constant; they keep on changing with age. Hence it has to be updated from time to time. We are being told

to link this identity with various services.

The third one in the trinity is mobile connectivity. Low-cost smart phones are in the market. Internet availability to all is in the process; some service providers have already started it.

The digital services available today in India are online shopping, mobile recharge, landline and electricity bill, cable TV bill, gas booking, restaurant and movie booking, home delivery of food, booking in railway, bus and cab etc. But health care and telemedicine have not yet reached to all. The most important is the education. Unless we educate the weaker section (those who lack literacy), Digital India cannot be implemented successfully.

Demerits

Let us now address the demerits of digitalisation. As per the information reported to and tracked by the Indian Computer Emergency Response Team (CERT-In), the number of cyber security-related incidents are increasing gradually. The common attacks in cyberspace are mainly of two types:

(1) Social Engineering and (2) Malware.

(1) Social Engineering, in the context of information security, refers to psychological manipulation of people into performing actions or divulging confidential information. These are prevalent in matters related to bank accounts and the like. Under Social Engineering comes the attacks of Phishing, Vishing and SMShing.

Phishing, in general, is with respect to a computer. It is the attempt to obtain sensitive information such as usernames, passwords and credit card details often for malicious reasons by disguising as a trustworthy entity in an electronic communication. For example, in the personal computer you receive an e-mail that you would have no access to your computer if you do not provide with some of your personal details immediately.

Vishing or Voice Phishing is the criminal practice of using social engineering over the telephone system to gain access to private, personal and financial information from the public for the purpose of financial reward. Just as in the case of via computer, attacks may come through phone calls also. In fact, this is gradually increasing. People are receiving calls from persons pretending to be, say the bank manager, that your account will be blocked if you do not furnish some confidential information. Even if you have a caller ID, the incoming call appears to be a valid one; this is done using a special software.

SMShing or SMS Phishing is the attack through SMS. You may receive a SMS from a bank informing about an unauthorised transaction from your account and it asks you to confirm your online details if you have not done this transaction. Once you go online you are sometimes asked to click a particular box which on opening asks for your account number, ATM PIN, etc. These are not at all received by the bank but instead someone else collects these confidential details.

(2) Malware is the short form of malicious software. Here information comes in the software itself, which may even lock the computer. The recent Malware in the news is named *Ransomware* where the user gets a threat that the computer would not perform unless a ransom money is paid to a certain bank account. Nearly a month back there was a ransom attack in the computer database in a private hospital in Kolkata. Luckily they had a backup of their data. But the entire hard disc had to be deposited in the cyber crime cell of Lalbazar, where the experts could do the needful.

Another type of malware is the *botnet* which is a kind of software application that

runs automatically in the internet. A number of internet-connected devices operate simultaneously. Recently there was a botnet attack by the name of *Mirai*. As a result all sensor-based devices and home routers for internet connection could not function. This incident happened abroad in October, 2016.

Following are some of the important factors for increase in cyber attacks (a) Unawareness among one and all: The users probably do not know much details about security factors. For example, on getting the threat of closure of bank account the senior or the very senior citizens may disclose all the details in panic about what would happen if their bank accounts cannot be operated.

(b) Unawareness of policies: Account holders must be clearly informed of the bank policies as to which information a bank can ask for and an account holder should not disclose anything other than those.

(c) Technical sophistication of attackers: Whichever lock is used, if the attackers are more powerful in terms of computational resources, there remains a possibility of the lock being broken. The security of the authentication details depends upon the endpoint devices. If the endpoint device is compromised, then the data will be hacked. Suppose in a mobile phone all the important passwords are saved but the phone itself is not password protected. All the data will be hacked in case the mobile phone gets stolen.

Recently there was a *0-day* attack. A 0-day is a computer software where many internet companies such as Zomato which provides information about various restaurants, Reliance Jio etc. store their data. On violating privacy and without the permission of the concerned authority, those data were stolen by the hackers. So one needs to be careful.

At my institution I.S.I. a number of research works on cryptography are already in progress; researchers are working on *bitcoin, blockchain* etc. which are used for secure financial transaction. Whatever protection is taken, if someone activates or responds unintentionally, the person cannot come out of the trap.

The march of technology has given us immense power and this has to be utilized properly for the benefit of all the human beings in the world for food, health and education. With the digital revolution, the world has become connected; we have information of all corners of the world. So we should make use of this technology for education. We already have distant education in a passive pre-recorded manner. Now we can go ahead and make the best use of this technology for interactive online virtual class-rooms.

One word of caution is that we should not become slaves of our inventions. This is harmful not just for the individual but for the entire society. You remain so engrossed with your smart phone that you remain isolated and forget the rest of the world. There are many instances of casualties on road, railway tracks of individual or of innocent people due to mobile phone use.

Another point of concern is the disposal of the integrated circuits after use. The integrated circuits are made up of not only silicon from sand but also many other materials which are toxic in nature. These integrated circuits have a specific life span; so on repeated use for a prolonged period, say after 10 or 15 years, these lose the efficiency and are to be disposed. But this practice is harmful to our mother earth; hence we need to develop eco-friendly technological products. ■

* This article is based on a lecture Dr Susmita Sur-Kolay delivered at the Institute on 5 December, 2017. Dr Sur-Kolay is Professor-in-charge, Computer and Communication Sciences, Indian Statistical Institute, Kolkata.