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Analysing Adoption Dynamics In Mobile Network Technologies: A Model–Based Approach To 3G, 4G And 5G

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Abstract

This paper investigates consumer adoption behaviours across three generations of mobile network technology 3G, 4G, and 5G. Using systematic mathematical modelling, including the Bass diffusion model and its extensions, this study examines leapfrogging, switching, and the impact of marketing efforts. Key insights are drawn from the Indian telecom sector's rapid 5G adoption and the decline of older technologies, providing strategies for optimizing network rollout and marketing.

Keywords: Bass Diffusion Model, Leapfrogging, Switching, Mobile Network Adoption, Adoption Rate.

1. Introduction:

Industrial technology adoption dynamics describe the process of introduction, acceptance, and assimilation of new technologies into industries. This would follow the phases of innovation, pioneer adoption, diffusion, and maturity. Adoption is influenced by several factors, such as economic viability, technology readiness, and compliance with regulation, labour adaptation, and competitive imperative. Adoption is usually described in models such as the Technology Adoption Lifecycle, Diffusion of Innovation Theory, and Technology Acceptance Model. Nevertheless, hindrances including initial costs, resistance to change, cyber security threats, and scalability concerns can limit adoption. Emerging trends including AI, automation, Industry, sustainable technologies, and block chain are determining the future of industrial technology adoption.

Technology substitution is the phenomenon where businesses or industries switch from one technology to another, typically to enhance efficiency, lower costs, or remain competitive. It may be done gradually or in a sudden move, depending on market needs and technological progress. Leapfrogging is when businesses or industries skip intermediate levels of technological advancement and adopt the latest technology directly. This is typical in developing countries where old infrastructure is bypassed in favor of sophisticated solutions, like going directly to mobile banking without extensive traditional banking systems. Switching and leapfrogging both have vital roles in defining industrial development, technological competitiveness, and economic progress.

The 3G network is the oldest communication standard for many people and has now become the "mobile standard". It is the third generation of mobile communication, working via signals transmitted between phones. Your phone sends and receives messages from the nearest base stations over the network managed by your mobile operator (Three, O2, Vodafone or EE in the UK). This enables you to make and receive calls and access the mobile internet. 3G is the successor to the earlier 2G technology. Looking back, we see that 3G brought unprecedented data transfer, access to multimedia services and seamless roaming. The third generation of mobile communication is based on packet data transfer. 3G also enables efficient use of channel resources and expands operating frequencies (400 MHz - 3 GHz). This allows the service providers to offer better services to more customers. Main features and characteristics include; Speed up to 2 Mbps; Bandwidth and data transfer capability increased high for sending/receiving large emails and large capacity. However, though the information is correct, 3G has now become popular and the model has followed the fourth and fifth generation slowly but steadily.

4G becomes the new standard for mobile phones. This IP-based network was developed in 2000 and has been used in several countries since 2010. Thus, all significant telecom players in the UK receive 4G straight off the because in case of 3G networks we cannot watch movies and TV series, which is easy to do with 4G. 3G has limited data speeds, while 4G networks provide high-speed Internet connections to all users.Many online services do not work well on 3G, but this is not the case with the 4th generation. The transition from 3G networks to 4G promises higher, more reliable, and improved data transmission. 4G allows people to stream videos and songs online, make phone calls and play computer games without delay. It also allows users to use their phones as a handy personal hotspot for laptops or other devices while on the go. 5G is the fifth generation of mobile network technology models that promises to provide peak data speeds in excess of GPS's, ultralow latency, greater reliability and more bandwidth compared to 4G. And what's interesting, 5G is a progression of the 4G standard, therefore having the same mix of technologies and full "backwards compatibility" with existing 4G infrastructure. Coverage in the UK was first introduced in major cities back in 2019. One of the key differences between 4G and 5G is transmission speed: 5G is around 20 times faster than 4G. It can still work for more users after that. The new model allows up to 1 million customers to be paid in a 1 square kilometre area. 5G is operated in different radio spectrum. This changes how the network would perform. With 4G, it performs at frequencies[1] that are below 6 GHz. With standard 5G, this operates at the range of frequencies[1] between 30 to 300 GHz. Long-term, 5G standards will allow the Internet of Things to work at scale. It connects all devices to the internet (from self-driving cars to "smart" electric kettles), informs vehicle control, and facilitates work in medicine, commercial printing, science, technology, and all other fields where it is inevitable. It is designed to send more data with lower latency compared to the third generation. 3G is around 200 Kbps to 2 Mbps, while 5G can go as high as 1 Gbps to 10 Gbps or more.

Latency-wise, 3G typically operates in frequency bands below 3 GHz, which offers good coverage but high data capacity. 5*G* uses different frequencies, such as frequencies below 6 GHz for broadband and millimetre wave frequencies above 24 GHz for advanced data. Using millimetre waves allows for more information to be sent, but requires more base stations because it has a shorter range. The most critical difference between 3*G* and 5*G* is that the carriers are slowly abandoning 3G, but 5G is the most important point of adoption.

This paper focusing on the adopters dynamic of technology and also the consumer behaviour influence the transition between the generations. Before adopting older Technology but some adopter adopting first initial technology then Newer Technology. In this paper we are trying to given an effective model by which we can examine the behaviour of switching & leapfrogging of technology in the place of older one.

2. Methodology:

2.1 Diffusion Models

In today's fast-pacing world we are always surrounded by newly emerged products: electronic cars, Bionic chips, Android/Google TV, television mobile phones, personal computers, tablets, etc. An industry manufactures is a new technological product and want to know at what rate the new process or product can penetrate the market so that it can regulate the production strategy accordingly or so that government can license to produce it in order to satisfy the future demands. The diffusion of innovation is a process by which an innovation is communicated through certain channels over time among the members of a social system. It is noted that the diffusion processes in general follow an S curve. Gupta and Srivastava [2], In his research article "A qualitative analysis of technological innovation diffusion" assumed that adoption of an innovation is essentially the outcome of learning or communication process and that the diffusion regime or social system is the one in which all the individuals have equal opportunity to adopt. The inherent assumption in these models is that the old technology is completely replaced by the new one. Where as in many cases particularly in developing countries more than one completing technologies coexist. Cases of multiple substitutions may be seen in many others. Multiple substitutions are the result of frequent innovation in a particular area i.e. economic viability of old technology, energy resources wood-coal, oil, natural gas and non conversional energy sources like biogas, solar energy Modelling technology diffusion processes was initially derived from theory of growth of a colony of biological cell in a medium. since the growth of a cell would be limited due to limited space.

2.2 Switching Diffusion Model

Switching [3] adoption is those who cease to use previous version of the generation and switch to the next newest generation services. Since that is satisfaction of primary Technology the adapters stop using the primary Technology all together and do not option any other similar Technology as the result they are

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considered to be removed from the system. But out of these dissatisfaction adopters who are already familiar to the primary Technology may option to switch to similar or substitute Technology. Has the diffusion process of a primary Technology is affected by switching to substitute Technology.

2.3 Leapfrogging Diffusion Model

Leapfrogging [4] is the behaviour of potential adopters skipping previous generation and directly adopting a newer generation services. This definition is already used by Danaher et al. (2001), Jiang and Jain (2012)[5] in studying diffusion of successive generation of products. According to leapfrogging model specified in methodology section, we have estimated leapfrogers demand for 3*G*, 4*G*, and 5*G* data services with and without considering price effect. Technology is what allows us to stay connected, provides us with unhindered access to information, makes life easier, and opens up incredible opportunities. Communication standards are rapidly moving to new levels of technical solutions, leading to new opportunities far beyond traditional communication. There are several levels of communication. The standards are 3*G*, 4*G*, and 5*G*, where the letter " G " stands for Generation and forms their chronology. The difference between 3*G*, 4*G*, and 5*G* lies primarily in the data transfer rate. It all began with the 1*G* standard, from which the technology gradually improved. The introduction of 5*G* across the globe, and a total shift is expected

2.4 Factors Influencing Leapfrogging vs. Switching

1. Infrastructure Development: Countries or regions with limited 4G rollout may seemore leapfrogging directly to 5*G*.

2. Cost of Transition: If 5*G* adoption costs (devices, tariffs) are similar to or cheaper than 4*G*, leapfrogging becomes more attractive.

3. Consumer Awareness: Marketing campaigns emphasizing 5*G* benefits may encourage leapfrogging.

4. Device Availability: Availability of affordable 5*G* smartphones influences adoption patterns.

5. Company Strategy: Telecom providers may promote leapfrogging by bundling 5*G* services with attractive offers.

3. Proposed Model:

Incorporating marketing mix variables with the marketing effort considered, the cumulative [6] and non-cumulative [7] market penetration (as a fraction of the market potential) can be represented by here p is coefficient of innovation, q in coefficient of imitation, $X(t)$ is cumulation marketing effort, and $x(t)$ is current marketing effort. We next demonstrate that the multiplicative factors for the single-generation GBM can be incorporated into the GNB model. Since market efforts are not expected to be the same across generations, we denote the current and cumulative marketing efforts for generation G by $X(t)$ and $x(t)$, respectively. Analogous to GBM, incorporating the effect of marketing efforts in equation yields Where $F(t)$ is cumulative and $f(t)$ is non-cumulative

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Taking into consideration the effect of marketing mix variables, we next examine the diffusion dynamics for a two-generation scenario. Before the introduction of G_2, the diffusion of G_1 follows the GBM i.e., $X(t)$ = Cumulative adoption function marketing effort and $x(t)$ = Current marketing effort.

Incorporating Marketing Mix Variables:

$$X(t) = \int_0^t x(t)\, dt$$

With the marketing effort considered, the cumulative and non-cumulative market penetration (as a fraction of the market potential) can be represented by

X(t) = Cumulative adoption function marketing effort and $x(t)$ = current marketing effort

$$F(t) = \frac{1 - e^{-(p+q)X(t)}}{\left(\frac{q}{p}\right) e^{-(p+q)X(t)} + 1}$$

Adoption rate

$$f(t) = \frac{(p+q)^2}{p} x(t) \frac{e^{-(p+q)X(t)}}{\left[\frac{q}{p} e^{-(p+q)X(t)} + 1\right]^2}$$

Here p is coefficient of innovation, q in coefficient of imitation, $X(t)$ is cumulating marketing effort, and $x(t)$ is current marketing effort.

We next demonstrate that the multiplicative factors for the single-generation *GBM* can be incorporated into the GNB model. Since market efforts are not expected to be the same across generations, we denote the current and cumulative marketing efforts for generation G by $X(t)$ and $x(t)$, respectively.

Analogous to *GBM*, incorporating the effect of marketing efforts in equation yields Where, $F(t)$ is cumulative and $f(t)$ is non-cumulative

$$F_1(t) = \frac{1 - e^{-(p_1+q_1)X_1(t)}}{\left(\frac{q_1}{p_1}\right) e^{-(p_1+q_1)X_1(t)} + 1}$$

$$F_2(t) = \frac{1 - e^{-(p_2+q_2)X_2(t)}}{\left(\frac{q_2}{p_2}\right) e^{-(p_2+q_2)X_2(t)} + 1}$$

$$F_3(t) = \frac{1 - e^{-(p_3+q_3)X_3(t)}}{\left(\frac{q_3}{p_3}\right) e^{-(p_3+q_3)X_3(t)} + 1}$$

where, $F_1(t)$, $F_2(t)$ and $F_3(t)$ are cumulative

$$f_1(t) = \frac{(p_1+q_1)^2}{p_1} x_1(t) \frac{e^{-(p_1+q_1)X_1(t)}}{\left[\left(\frac{q_1}{p_1}\right) e^{-(p_1+q_1)X_1(t)} + 1\right]^2}$$

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$$f_2(t) = \frac{(p_2+q_2)^2}{p_2} x_2(t) \frac{e^{-(p_2+q_2)X_2(t)}}{\left[\left(\frac{q_2}{p_2}\right) e^{-(p_2+q_2)X_2(t)} + 1\right]^2}$$

$$f_3(t) = \frac{(p_3+q_3)^2}{p_3} x_3(t) \frac{e^{-(p_3+q_3)X_3(t)}}{\left[\left(\frac{q_3}{p_3}\right) e^{-(p_3+q_3)X_3(t)} + 1\right]^2}$$

Taking into consideration the effect of marketing mix variables, we next examine the diffusion dynamics for a two-generation scenario. Before the introduction of G_2, the diffusion of G_1 follows the GBM i.e.,

$$Y_1(t) = m_1 F_1(t) = m_1 \frac{1 - e^{-(p_1+q_1)X_1(t)}}{\left(\frac{q_1}{p_1}\right) e^{-(p_1+q_1)X_1(t)} + 1}, \quad t < \tau_2$$

After G_2 is introduced at time τ_2, some potential adopters of G_1 will leapfrog to G_2. We assume that the leapfrogging multiplier under this scenario is $F_2(t - \tau_2)$, because the cumulative market effort for G_2 is expected to influence the rate of leapfrogging to G_2. Similar to equation, the rate of leapfrogging between G_1 and G_2 equals

$$u_2(t) = \lim \frac{m_1 \left[F_1(t) - F_1(t-\delta)\right] F_2(t-\tau_2)}{\delta}$$

$$u_2(t) = m_1 f_1(t) F_2(t-\tau_2)$$

$$= m_1 \frac{(p_1+q_1)^2}{p_1} x_1(t) \frac{e^{-(p_1+q_1)X_1(t)}}{\left[\left(\frac{q_1}{p_1}\right) e^{-(p_1+q_1)X_1(t)} + 1\right]^2} \frac{1 - e^{-(p_2+q_2)X_2(t-\tau_2)}}{\left[\left(\frac{q_2}{p_2}\right) e^{-(p_2+q_2)X_2(t-\tau_2)} + 1\right]}$$

$$u_2(t) = \lim \frac{m_1[F_1(t) - F_1(t-\delta)]F_2(t-\tau_2)}{\delta} = m_1 f_1(t) F_2(t-\tau_2)$$

Switching (sequential upgrade)

$$w_2(t) = m_1 F_1(t) f_2(t-\tau_2)$$

$$w_2(t) = m_1 \frac{(p_1+q_1)^2}{p_1} x_1(t) \frac{e^{-(p_1+q_1)X_1(t)}}{\left(\frac{q_1}{p_1} e^{-(p_1+q_1)X_1(t)} + 1\right)^2} \frac{\left(1 - e^{-(p_2+q_2)X_2(t-\tau_2)}\right)}{\left(\frac{q_2}{p_2} e^{-(p_2+q_2)X_2(t-\tau_2)} + 1\right)^2}, \quad t \geq \tau_2$$

Regarding the rate of switching between G_1 and G_2, similar to the scenario without marketing mix variables, we assume that the switching multiplier is

$$\frac{m_1 F_1(t)}{m_1 F_1(t) - u_2(t)} f_2(t-\tau_2)$$

hence the rate of switching between G_1 and G_2 is once the rates of leapfrogging & switching are determined the rates of adoption for G_1, G_2 can be obtained.

$$y_1(t) = m_1 f_1(t)[1 - F_2(t-\tau_2)], \qquad t \geq \tau_2$$

Where, $m_1 f_1(t)$ The standard Bass Diffusion rate of G_1, $1 - F_2(t - \tau_2)$ The fraction of adopters not leapfrogging to G_2 and $y_1(t)$ = generalized Bass Model (initially)

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$$y_2(t) = m_2f_2(t)[1 - F_3(t - \tau_3)] + m_1f_1(t)[F_2(t - \tau_2)], \qquad t \geq \tau_2$$

Where, $F_2(t - \tau_2)$ is leapfrogging multiples when G_2 introduced at time τ_2 , m_1,m_2 are market potential of G_1 & G_2 and $Y_2(t)$= generalized Bass Model (when there are switching from G_1 and G_2) $F_2(t - \tau_2)$Is leapfrogging multiplier when G_2 introduced at time τ_2 We construct a model based on the above study, when consumer switch from generation G_1 to generation G_2 and generation G_2 to generation G_3 and leapfrog from G_1 to G_3 also direct adoption leapfrogging generation of the G_3

$y_3(t) = m_3f_3(t) + m_2f_2(t)[F_3(t - \tau_3)] + m_1f_1(t)[F_2(t - \tau_2)],\ \ t \geq \tau_3$

$y_3(t)$= generalized Bass Model (when switching from G_2 and G_3)

$F_3(t - \tau_3)$ Is leapfrogging multiplier when G_3 is introduced at time τ_3 m_1, m_2, m_3 are market potential of G_1, G_2 and G_3 respectively. The above equations are rate of adopter can be easily obtained by these equations from G_1 to G_2 and then G_2 to G_3.

Leapfrogging from G_2 to G_3 and from G_1 to G_3

$$u_3(t) = \lim \frac{m_1[F_2(t) - F_2(t - \delta)]F_2(t - \tau_3)}{\delta}, \quad t \geq \tau_3$$

$$= m_1f_1(t)[1 - F_2(t - \tau_2)] + u_2(t) - w_2(t), \qquad t \geq \tau_3$$

Rate of switching between G_1 and G_2

$$w_2(t) = m_1f_2(t)[F_3\,(t - \tau_3)], \qquad t \geq \tau_2$$

Where, $F_1(t)$ = cumulative adoption function for G_1, $f_1(t)$ = standard Bass Diffusion rate for G_1, $F_2(t - \tau_2)$ = fraction of adopters switching to G_2 after time τ_2, m_1,m_2 = market potential for G_1 and G_2 respectively.

If $F_3(t{-}\tau_3)$ represents the cumulative adoption function of G_3 and τ_3 is the time at which G_3 becomes available, the switching rate $w_3(t)$ can be modelled as

$$w_3(t) = m_2f_2(t)[1 - F_3(t - \tau_3)], \qquad t \geq \tau_3$$

Where, m_2 = market potential of G_2, $f_2(t)$ = Diffusion rate for G_2, $F_3(t - \tau_3)$: fraction of adopters switching from G_2 to G_3

From above model, the adoption of technology is shaped by two singular categories of users. Certain users adopt new technologies directly using leapfrogging, while other users take a slower approach, adopting technologies incrementally. The total adoption rate comes from the total impact from both these behaviours. Leapfrogging hastens adoption by permitting users to bypass obsolete technologies, while incremental adoption moves along a standard path. Knowing the proportion of these two approaches is important in anticipating adoption movements and planning for the any new technology to ensure ease of transition.

4. Application of Model:

Our proposed model illustrates that both leapfrogging and switching play a significant role in affecting the adoption of technology. Availability and ease are major determinants of the adoption of any given technology. The adopters accept newer technologies on the day of their release, while in some instances, adopters wait until improvements are done before adopting the technologies. Some consumers bypass early generations and adopt the newest version directly, a process referred to as leapfrogging. Others adopt an earlier generation first before switching to a newer one, which we call switching. This model is used across different industries, such as:

Automobile Industry: Some customers first embraced B2-type engines, then B4 and eventually B6 engines. Others, however, went straight to adopting the B6 engine without ever embracing B2 or B4.

Consumer Electronics: Devices like televisions, refrigerators, air conditioners, and smartphones exhibit this phenomenon. Some customers change in a sequential manner, while others bypass the middle generations and adopt the current ones directly.

Telecom Sector: We notice the same evolution from 2G to 3G to 4G and then 5G, with some consumers upgrading in stages and some bypassing generations.

Healthcare and Medical Devices: Advanced medical technology, including implantable devices, robotic surgery, and wearable health monitors, tends to get adoption phase-wise. Some healthcare providers and hospitals upgrade gradually, while others bypass directly to the latest technologies.

Renewable Energy: Some companies and residents initially use conventional solar panels before upgrading to more efficient models, while others go directly for the latest technology, including superior photovoltaic cells or intelligent energy grids.

E-commerce and Digital Payments: The shift from cash transactions to credit/debit cards, mobile wallets, and finally crypto currency-based transactions is a similar case. Some adopt each stage in succession, while others leapfrog to newer modes of payment.

Education Technology (EdTech): Online learning platforms' adoption, ranging from CD-based learning to web-based courses to AI-driven individualized education, is also similarly characterized by switch and leapfrog.

With the assistance of our model, we are able to accurately analyse and forecast consumer adoption trends, enabling businesses and policymakers to gain a better insight into market dynamics. By emphasizing the effects of switching and leapfrogging on adoption levels, this model gives us useful insights into technological diffusion across sectors.

4.1 Application Of Model In Telecom Industry:

In the field of mobile networking there are three major communication 3G, 4G and 5G

3G adoption: $f(t)$ gress based on innovation and imitation coefficients.

4G adoption: some 3G user switch $w(t)$ while others leapfrog of 5G

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5G adoption: leapfrogging and switching dynamics influence $F_3(t)$

The concept of leapfrogging and switching in the adoption of mobile network technologies 3G, 4G and 5G we can model as

Leapfrogging (3G to 5G):

When the adopters leapfrogging from $3G$ to $5G$. The rate of leapfrogging can be expressed as

$u_2(t) = m_1 f_1(t) F_2(t - \tau_2)$

Where, m_1 = Market potential of 3G, $f_1(t)$= Adoption rate of 3G, $F_2(t - \tau_2)$ = Cumulative influence of 5G marketing (starting at τ_2)

For leapfrogging directly to 5G

When adopters not adopting $3G$ and $4G$ technology and direct adopting $5G$ technology then $F_2(t - \tau_2)$ Captures the adoption efforts for 5G

A higher $F_2(t - \tau_2)$ (e.g., through aggressive 5G campaigns) will increase encouraging consumers to skip 4G.

Switching (Sequential Adoption 3G to 4G to 5G)

When the adopter adopts $3G$ to $4G$ then $5G$ technology. The rate of switching from 3G to 4G is

$w_2(t) = m_1 f_2(t)[F_3(t - \tau_3)]$

Where, $F_1(t)$ = Cumulative adoption of 3G, $f_2(t - \tau_2)$ = Diffusion rate of 4G after its launch τ_2

The rate of switching from 4G to 5G is

$w_3(t) = m_2 f_2(t)[1 - F_3(t - \tau_3)]$

Where, m_2 = Market potential of 4G

$F_2(t)$ = Cumulative adoption of 4G, $f_3(t - \tau_3)$ = Diffusion rate of 5G To model the combined adoption

For 3G Users

$y_1(t) = m_1 f_1(t)[1 - F_2(t - \tau_2)]$

Where, $[1 - F_2(t - \tau_2)]$ Reflects the fraction of 3G users not leapfrogging to 5G

For 4G Users

$y_2(t) = m_2 f_2(t)[1 - F_3(t - \tau_3)] + m_1 f_1(t)[F_2(t - \tau_2)$ Combining Adoption by $4G$'s own diffusion = $m_2 f_2(t)$

Adoption from 3G users switching or leapfrogging = $m_1 f_1(t)[F_2(t - \tau_2)]$

For 5G Users

$y_3(t) = m_3 f_3(t) + m_2 f_2(t)[F_3(t - \tau_3)] + m_1 f_1(t)[F_2(t - \tau_2)]$

Combining Direct diffusion of 5G = $m_3 f_3(t)$

Contributions from 4G users switching = $m_2 f_2(t)[F_3(t - \tau_3)]$

Leapfrogging from 3G = $m_1 f_1(t)[F_2(t - \tau_2)]$

Insights from the model

Leapfrogging to 5G If $F_2(t-\tau_2)$ (marketing of 5G) is strong and $F_2(t-\tau_2)$ (diffusion rate of 4G) is weak, leapfrogging dominates.

Sequential adoption

Strong $f_2(t)$ and $F_3(t-\tau_3)$ drive smoother transitions from 3G to 4G to 5G

Late Adopters

Slower diffusion rates $f_1(t)$, $f_2(t)$, $f_3(t)$ reflect resistance to upgrades. Using specific data on market potentials (m_1, m_2, m_3) diffusion coefficients (p, q) and marketing efforts $X(t)$, we could numerically simulate adoption trends and validate them against real-world patterns.

Leapfrog to 5G

When 4G comes out 5G may be adopted even without trying out 4G, this might happen because of dramatic increase in performance including speed and other aspects. Expected more favourable pricing plans compared to prior generations. An expansion of 5G networks and its different services existing in place of full adoption of 4G.

Reasons for Leapfrogging

4G for example may have been regarded to be inadequate by consumers seeking a mobile data upgrade by the time availability of the mobile spectrum [10] expanded. Mobile telecommunications adoption over the 5G network expects discounts and offers attaching a lot of value and what may be mentioned as subsidies. Particularly those people who do not want to go through the upgrade process and those who do not want multiple updates.

Reason of Switching

3G to 4G: Most consumers of private telecom companies like Jio, Airtel, and Vodafone adopted 4G when 3G networks were phased out. Reasons include improved speeds and services of 4G. Discontinuation of 3G services by most companies. Affordable 4G-enabled smart phones.

4G to 5G: After the introduction of 5G, many 4G users have been upgrading to 5G. because the promise of significantly higher speeds, lower latency, and better connectivity. It increasing availability of affordable 5G devices also Influence of peer adoption and marketing.

4.2 Behavioural Patterns Observation:

The behaviour of the consumers via the technological shifts and the concepts of changing and leapfrogging mobile network technologies [9] can be analysed through the evolution of technologies.

S.No.	Consumer Group	Adoption Path	Reason for Behaviours
1	Leapfrogging	3G to 5G	Avoid intermediate costs; better feature of 5G
2	Sequential Switches	3G to 4G to 5G	Gradual adoption as technology becomes mainstream

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3	Late adopters	3G to 4G / 4G to 5G	Resistant to frequent upgrades; adopt only when necessary
4	Non-Adopters	Remain 3G or 4G	Content with existing technology or constrained by cost

Table 1

According to leapfrogging model specified in methodology section, we have estimated leapfrogers demand for 3G, 4G, and 5G data services with and without considering price effect. Technology is what allows us to stay connected, provides us with unhindered access to information, makes life easier, and opens up incredible opportunities. Communication standards are rapidly moving to new levels of technical solutions, leading to new opportunities far beyond traditional communication. There are several levels of communication. The standards are 3G, 4G, and 5G, where the letter "G" stands for Generation and forms their chronology. The difference between 3G, 4G, and 5G lies primarily in the data transfer rate. It all began with the 1G standard, from which the technology gradually improved. The introduction of 5G across the globe, and a total shift is expect, leapfrogging is the act of skipping adoption of an intermediary level device i.e. 4G and directly adopting 5G once there is an expansion of the network from the last technology 3G.

5. Numerical Discussion: We will simulate the model with different values of p & q observe how the adopters behavior change, this will enable to estimate adoption rate in which market potential, market effort is impact by switching leapfrogging.

Parameters for Market Potential, Market Effort

Symbol	**Meaning**	**Value**
p_1, q_1	For 3G innovation and imitation coefficients	0.01, 0.4
p_2, q_2	For 4G coefficients	0.015, 0.45
p_3, q_3	For 5G coefficients	0.02, 0.5
m_1, m_2, m_3	Market Potential of 3G, 4G, 5G	100, 150, 200
$X_1(t), X_2(t), X_3(t)$	Marketing effort	0.05t, 0.06t, 0.07t
τ_2, τ_3	Introduction delays of 4G, 5G	6, 12 (months)

Table 2

Estimated Adoption rate cumulative adoption, leapfrogging & switching for various time (month)

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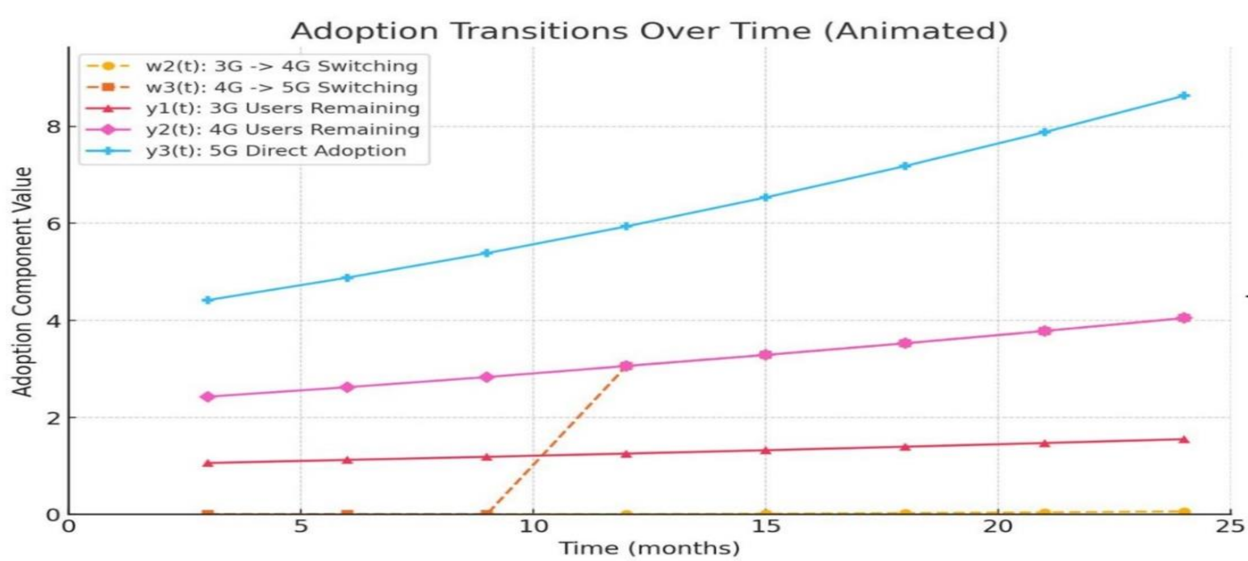
t	$X_1(t)$	$X_2(t)$	$X_3(t)$	$F_1(t)$	$f_1(t)$	$F_2(t)$	$f_2(t)$	$F_3(t)$
3	0.15	0.18	0.21	0.00154	0.0106	0.00281	0.01622	0.00442
6	0.3	0.36	0.42	0.00318	0.01124	0.00584	0.01753	0.0093
9	0.45	0.54	0.63	0.00492	0.01191	0.00912	0.01893	0.01469
12	0.6	0.72	0.84	0.00676	0.01262	0.01267	0.02044	0.02063
15	0.75	0.9	1.05	0.0087	0.01336	0.01649	0.02205	0.02718
18	0.9	1.08	1.26	0.01077	0.01415	0.02061	0.02377	0.03437
21	1.05	1.26	1.47	0.01295	0.01498	0.02505	0.02562	0.04228
24	1.2	1.44	1.68	0.01527	0.01586	0.02984	0.02758	0.05094

t	$f_3(t)$	$F_2(t-\tau_2)$	$F_3(t-\tau_3)$	$u_2(t)$	$u_3(t)$	$w_2(t)$	$w_3(t)$
3	0.02211	0	0	0	0	0	0
6	0.02442	0	0	0	0	0	0
9	0.02694	0.00281	0	0.00334	0	0	0
12	0.02969	0.00584	0	0.00737	0	0	3.06558
15	0.03268	0.00912	0.00442	0.01219	0.00585	0.00974	3.29285
18	0.03591	0.01267	0.0093	0.01793	0.013	0.02211	3.53296
21	0.0394	0.01649	0.01469	0.02471	0.02165	0.03763	3.78591
24	0.04315	0.02061	0.02063	0.03269	0.03205	0.0569	4.05153

Table 3

From above table we draw a graph in between adoption component value and time



Graph 1

3G, 4G and 5G lines show how users remain or adopt each generation. Leapfrogging $u_3(t)$ captured users jumping directly from 3G to 5G. Switching $w_2(t)$ and $w_3(t)$ show transitions from 3G to 4G and 4G to 5G respectively. The curves reflect consumer trends and market readiness for each generation. This insight can guide telecom rollout strategies and phasing out of legacy networks.3G declines steadily as users migrate to newer technologies. 4G (y_2) initially grows but later declines due to 5G switching and leapfrogging, 5G shows consistent direct adoption indicating market dominance. Leapfrogging $u_3(t)$ captures users bypassing 4G and directly adopting 5G after t = 12.5 $w_2(t)$ (3G->4G) and $w_3(t)$ (4G->5G) activate post G2 and G3 launches. Telecoms should focus on 5G rollout and phasing out legacy networks.

Leapfrogging from 3*G* to 5*G* (u_2) starts increasing after 4*G*'s influence diminishes. It picks as 5*G* marketing become stronger and more appearing. Switching from 3G to 4G (w_2) is highest when 4*G* adoption is active. Switching from 4*G* to 5*G* (w_3) dominates after years 10, as 5*G* becomes the leading technology.

6. Conclusion:

The adoption of technology in India depends not only on the emergence of new innovations but also on their availability and stability over a period of time. Some potential adopters do not want to adopt the present generation of technology and wait for new generations to arrive. In response to this, companies regularly come up with new technologies with higher versions, gaining trust and minimizing risks and providing greater benefits. Consequently, most users switch from previous technologies to newer ones. Meanwhile, some early adopters of an original technology generation still switch to its newer versions. This research analyses the effects of leapfrogging and switching behaviour on network infrastructure optimization and mobile network evolution. It is important to understand these transitions in order for companies to improve user experience, enhance market strategies, and achieve sustainable technological development. Leapfrogging becomes significant in the later years as user directly adopt 5*G*, bypassing 4*G*. Switching rates highlight the sequential adoption behaviour driven by infrastructure availability and marketing efforts. This paper concludes that understanding leapfrogging & switching behaviour is essential for optimizing mobile network development, improving digital connectivity and insuring a smooth transition between one generation to another generation.

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