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A multi-level perspective on 5G transition: The China case

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ABSTRACT

The expedite to network economy during the COVID-19 pandemic has raised the question of how to induce and sustain a societal and industrial transformation towards a more networked world. Among the driving forces behind network economy, the commercialization of 5G, the fifth generation of mobile technologies, is especially noteworthy. How does 5G induce such a transition? How do countries respond? are questions deserving more investigation. However, most discussions of 5G have been confined to standardization or standard-setting. To take into accounts interactions between technology and economy, we adopt Geels' (2002) multi-level perspective to put 5G transition in the social-technical context. We choose China as an influential case and deploy mixed methods to analyze a variety of data sources. The results show a rich picture of technological transition, including: 1) 5G standard-setting as a transition trigger in the global level; 2) IoT incubation in the niche level; and 3) regime configuration in the national level. We help transcend the limitation of standardization studies, extend the scope of transition studies into network economy, and introduce more industrial dynamics.

1. Introduction

The expedite to network economy during the COVID-19 pandemic has raised the question of how to induce and sustain a societal and industrial transformation towards a more networked world. Network economy is not a new thing since the world has been deeply embedded in a fabric interwoven by network infrastructure (Zammuto et al., 2007). What is new is that the pandemic has triggered transformations not only in a global scale, but also in a massive scope on every aspect of political, economic and social life. We have seen the rise of pandemic information systems, the move to on-line education, the increase in flexible work arrangements, and the intensification of network economy across many sectors (Whitelaw et al., 2020). The pandemic will end eventually, but the momentum it generated might have long-lasting effects. Network economy will continue making new ways of organizing and working possible (Brynjolfsson and McAfee, 2014), connecting humans and machines via a vast array of internet of things (IoT) applications (Shafique et al., 2020), and incorporating artificial intelligence (AI) as a component to augment and automate increasingly more functions and processes within as well as across organizations (Kellogg et al., 2020). It is therefore foreseeable a transition towards a more networked economy and society.

Among the driving forces behind network economy, the commercialization of 5G, the fifth generation of mobile technologies, is especially noteworthy. The advent of 5G and the outbreak of the pandemic were about the same time. The International Telecommunication Union (ITU) has been promoting 5G as the global telecommunication standard for years. The technical specifications have been drafted by members of the 3rd Generation Partnership Project (3GPP), which provides network solutions, technical specifications of telecommunications equipment, and terminals through the discussion and election of the technical proposals advocated by individual members. But not until Korea Telecom (KT) launched the world's first nationwide commercial 5G network in 2019, have countries around the world accelerated their commercialization of 5G.[1] As an all-encompassing standard, 5G holds a promise to integrate and reign the digital world through the convergence of wireless networks, applications and devices (Rommer et al., 2019).

How does 5G induce such a transition? How do countries respond? are questions deserving more investigation. However, due to the advocacy of standard development organizations (SDOs) such as ITU, most discussions of 5G have been confined to standard setting regarding the structure of mobile communication networks, and the applications on

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[1] Ericsson (2019), "Ericsson 5G is live in South Korea." Retrieved from https://www.ericsson.com/en/cases/2019/korea-telecom-has-switched-on-5g, last visited on June 17, 2022.

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them (Boccardi et al., 2014; Palattella et al., 2016; I. et al., 2016). In other words, they treated 5G, or the succession of mobile communication networks from generation to generation, as a standard-triggered, network-centric process. The imperatives were then geared towards negotiating and bargaining over candidate standards, and constructing the network according to the agreed standards. This network-based view worked fine before 5G when generic technology standards dominated and guided the evolution and application of networks. During the eras from the second generation (2G) to the fourth generation (4G), all users in the network had to follow the same specifications to develop equipment and devices, or provide products and services, the "one-size-fits-all" network (Agarwal and Agarwal, 2014). However, in today's 5G era, the focus has shifted from promoting standards by network providers to developing scenarios for network users, this is called "scenario-based" slicing (Kurtz et al., 2018; Oughton et al., 2018). Different scenarios will be treated separately based on their characteristics, and connected to the specific network slices which are designed especially for them. This may change the interactions among SDOs, network providers and its users, and challenge the traditional network-based, top-down view.

In the paper, we adopt the multi-level perspective (MLP) proposed by Geels (2002) to put 5G in a social-technical context. The adoption of MLP has three merits. Above all, it brings in more interactions and dynamics between technology and economy in 5G transition. By so doing, we are better to broaden the scope of the network-based view on 5G, which has been too narrowly defined by standardization. In addition, the multiple-level investigation helps shed lights on the linkages of technologies, policies, industries, markets and other related fields, which provide a selection mechanism and a reference framework for actors to interact and coevolve with their environments. Finally, the multiple-level investigation also helps evaluate the actors' responses by observing how they align or misalign with the directions of changes during technological transition.

We conduct our analysis in two stages. We begin with a discussion of theories with the aim of proposing an analytical framework for appreciating the phenomenon of 5G. The framework is then exemplified by the case of China's technological transition towards 5G. The case selection is based on the criteria of influential cases (Seawright and Gerring, 2008) since China as an aggressive promoter of 5G has a disproportionate amount of influence over the issues regarding 5G transition. The rest of the paper is structured as follows. Section 2 reviews the literature and proposes the analytical framework. Section 3 describes the case selection and methodology. Section 4 presents the empirical analyses. Section 5 concludes.

2. Theoretical discussion

2.1. The network-based view

Technological transitions have long been one of major concerns for management of technology, where technological transitions are seen as sources of creative destruction (Abernathy and Clark, 1993), drivers of organizational ecological change (Tushman and Anderson, 1986), or opportunities for innovation and entrepreneurship (Utterback, 1994). However, in mobile communication technologies, technological transitions are often treated as rounds of standard setting and standardization in a top-down manner, from SDOs to network constructors, operators, service providers, and finally to their users (Funk and Methe, 2001; Leiponen, 2008). Generations of mobile communication technologies, by definition, are generations of technical specifications, drafted and promoted by standard setting organizations such as the 3GPP. Accordingly, the succession from one generation to the next often means an upgrading of the network infrastructure based on new technical specifications.

The network based view has advantages when the network structure is unified and stable, since the focus on technical standard evolution and application may help reduce uncertainties, facilitate synchronizing disjointed technical innovations into a single systemic innovation, and enhance the market development in a stable direction (Funk and Methe, 2001). Before 5G, the successions basically followed a generic model where standards dominated the evolution of the network and its applications. All users in the network had to follow the same specifications to develop equipment and devices, or provide products and services, in what is known as the "one-size-fits-all" network (Agarwal and Agarwal, 2014). As a consequence, prior work usually treated 5G as technical standard evolution based on the generic model of networks (Jeon et al., 2020; Lemstra, 2018; Teece, 2020; Wang et al., 2021).

However, 5G presents a departure from its predecessors' generic to a differentiated model (I. et al., 2016). Such departure is manifested in three ways (Fig. 1). Firstly, different from previous eras which mainly connect people, 5G has an ambition to connect not only people, but also things, machines, vehicles and everything through networked products and services. The chairperson of the 3GPP RAN plenary meeting, Balazs Berteny, wrote that "we need to maximize the economies of scale around 3GPP's 5G radio and system standards, redefining all industries through a single platform for all connectivity applications."[2] Secondly, 5G also holds a promise to provide massive, high-capacity, high-reliability and low-latency connectivity to support a variety of scenarios such as smart cities, VR and self-driving cars. Thirdly, as a consequence, in 5G, different scenarios will be treated separately based on their characteristics, and connected to the specific network slices which are designed especially for them; this is called "scenario-based" slicing (Kurtz et al., 2018; Oughton et al., 2018). The focus thus shifts from promoting standards by network providers to developing scenarios for network users, which may challenge the traditional network-based, top-down process.

For example, to develop scenarios for self-driving cars in specific locations will require the collaboration among multiple stakeholders, including SDOs in negotiating the standards regarding the Internet of Vehicles (V2X), national or local governments in drafting regulations for safety issues, and scenario developers in defining the usage and architecture of the network. Either SDOs, national or local governments, or scenario developers can take the lead in guiding the development of self-driving cars as well as shaping its network evolution.

2.2. The multi-level perspective

The network-based view assumes the globalization of standards and network specifications, which focuses only on technological changes, while neglecting changes from other fields, such as political, economic, environmental, and social. In recent years, research on technological transitions, particularly those towards sustainability, has shown that the transition is a complex and intertwined long-term process that affects actors, technologies and institutions at the same time (Markard et al., 2012; van den Bergh et al., 2011). One of the central approaches that describes and analyzes such complex transformation processes is the multi-level perspective (MLP) (Geels, 2002, 2006; Fuenfschilling and Truffer, 2016). It sees socio-technical transitions that develop through interactions between three analytical levels: socio-technical regime, technological niche, and landscape. These levels are not ontological descriptions of reality, but analytical and heuristic concepts to understand the complex dynamics of sociotechnical changes.

The level of socio-technical regime, also the meso-level, accounts for stability of existing technological development and the occurrence of trajectories; the level of technological niche, also the micro-level, accounts for the generation and development of radical innovations; and the level of landscape, also the macro-level, accounts for slow-changing external factors, providing gradients for the trajectories (Geels, 2006).

[2] Bertenyi, "5G Standards leadership – beyond the numbers." Retrieved from https://www.bell-labs.com/var/articles/5g-standards-leadership-beyond-numbers/, last visited on March 17, 2021.

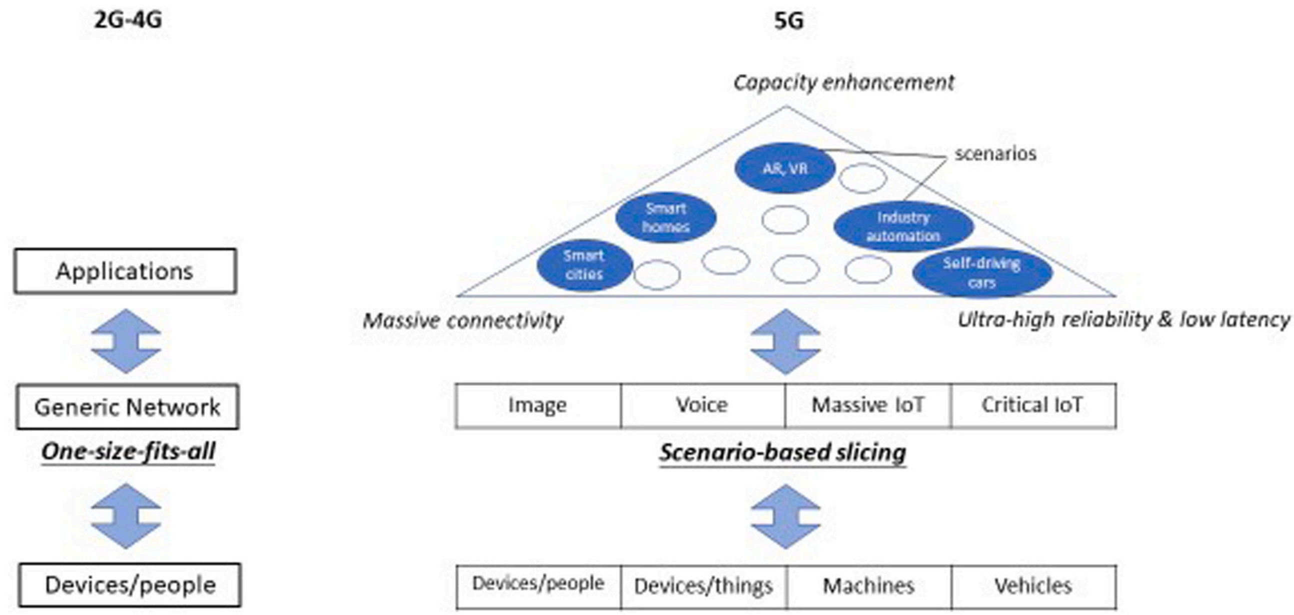

Fig. 1. Comparison of 2G–4G and 5G.

The relationship and interactions among the levels are quite flexible and dynamic, leaving room for adaptation and interpretation. The seeds for change might germinate at the micro-level when niches are produced and geared to the problems of existing regimes, as in the cases of disruptive innovation (Christensen, 1997); in the meso-level when internal dynamics of socio-technical elements cause tensions and create window of opportunities for technological changes, as in the case of steamships (Geels, 2002); or in the macro-level when external technological changes put pressure on regimes and trigger regime reconfiguration. Geels and Schot (2007) also provide four pathways of technological transition: 1) technological substitution, 2) transformation, 3) reconfiguration, and 4) de-alignment cum re-alignment, to take into accounts the interactions between incumbents and new entrants.

2.3. A synthesis: MLP for 5G transition

The flexibility of MLP allows us to develop an analytical framework for appreciating the technological transition caused by 5G. The literatures on long-term change processes for realizing socio-technical systems highlight the coevolution of institutional and technological elements into a highly institutionalized configuration that enables the fulfillment of specific societal functions (Geels, 2002; Smith et al., 2005). Such coevolution may occur within and across levels.

Considering the characteristics of 5G, we adapt from Geels (2002) to propose a three-level analytical framework for appreciating 5G transition (Fig. 2). The level of landscape, also the global level, refers to the mobile communication environment in which all nations will take part to construct a global digitalized world. The level of socio-technical regime, the national level, refers to the mobile communication regime, which is developed, sustained and transformed in the country under investigation. The level of technological niche, also the niche level, refers to the technological or market niche for novelties like IoT innovations, because they target directly the needs of user groups instead of the network. Again, the relationship and interactions among the three levels are quite flexible and dynamic. The transition processes could begin at the global level, when external shocks like the pandemic and 5G open window of opportunity for change; at the niche level, when new markets of IoT innovations emerge to challenge the old regime or create a new one; or at the national level, when conflicts between elements in the regime cause tensions and force the regime to change. In the following, we will introduce the three levels one by one.

2.3.1. The global level: mobile communication landscape

In the mobile communication area, the global level is the global environment for mobile communications, which is usually shaped by a handful of SDOs. For example, in its "Recommendation ITU-R M.2083", ITU, one of the major SDOs, has introduced three main scenarios of 5G: Enhanced Mobile Broadband (eMBB), Ultra-Reliable and Low Latency Communications (URLLC), and Massive Machine Type Communication (mMTC) to promote the development of 5G.[3] Where eMBB reflects the evolution of technical standards to enhance the 3G and 4G data services used by individual subscribers of traditional telecommunications networks; while the other two scenarios, mMTC and URLLC, are technical specifications in response to IoT scenarios, designed for enterprise- and industrial-level applications.

As shown in Table 1, 5G presents a departure from its predecessors' generic to a differentiated model. During 2G to 4G, the network infrastructure, applications and devices all followed standard-driven specifications, and standards evolved to improve the performance of the network in terms of transmission bandwidth and speed. In 5G, the relationship between the network and its users is reversed. The main technological features of the specifications released by 3GPP support different scenarios, and thereby slice the network infrastructure. The applications then facilitate the changes in devices, standard setting and network infrastructure.

2.3.2. The national level: mobile communication regime

Socio-technical regimes are "highly institutionalised regulative, normative and cognitive structures, e.g. norms, standards, values, cultural expectations or regulations, which have evolved in accordance with certain technologies" (Fuenfschilling and Truffer, 2016). 5G has the potential to redefine scenarios and applications, a potential that will have more effect on national policies and domestic industry and market structures than on other elements (Frieden, 2020). Therefore, at the national level, we pay more attention to the policy and industry/markets

[3] ITU (2015), "Framework and overall objectives of the future development of IMT for 2020 and beyond." Retrieved from https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf, last visited on June 17, 2022.

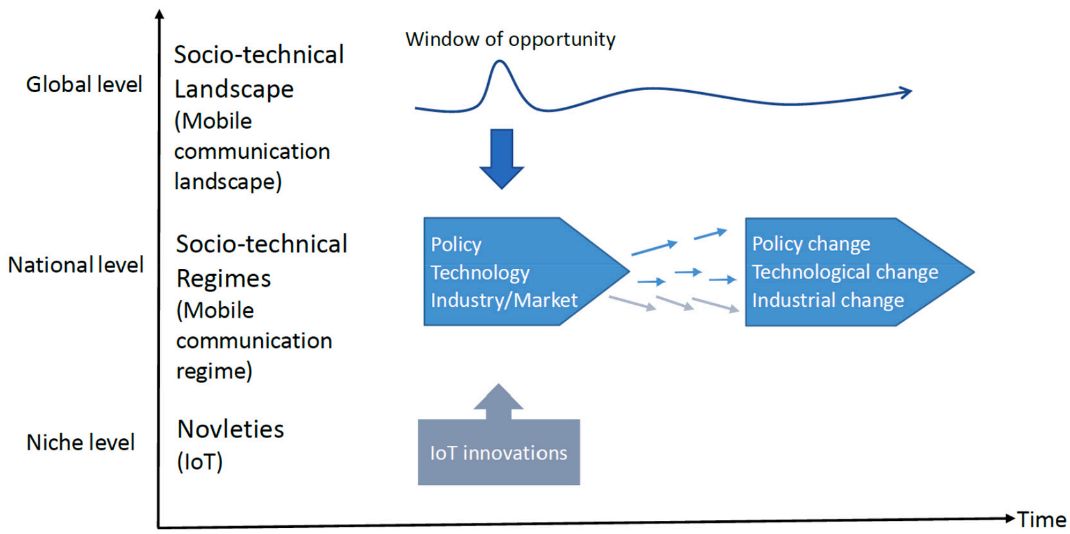

Fig. 2. The MLP framework for 5G transition.

Table 1
Comparison of generic and differentiated models.

	Generic model	Differentiated model
Generations	2G to 4G	5G
Focus	Network-based	Scenario-based
Standard setting	Technology evolution for improving network performance	Deep convergence of technology evolution and business intent of various scenarios
Network infrastructure	One-size-fits-all	Scenario-based slicing
Applications	Traditional services	Scenario applications
Devices	Subscribers to mobile telecom operators	People, things, Internet of everything
Direction of change	Standard setting ➔ network infrastructure ➔ applications ➔ devices	Applications ➔ devices ➔ standard setting ➔ network infrastructure

in mobile communication regimes: national telecommunication policy may respond to the global change of 5G standard setting; the industrial structure may affect and reflect industrial competition. We can use changes in these two elements as lenses through which to observe and trace institutional changes in the regime.

The first specific institutional change is about industrial policy. On the one hand, mobile communications in most countries are highly regulated due to the concerns on industrial development and national control. Therefore, national policies will actively respond to the global change of 5G standard setting, such as the adoption and promotion of global standards. On the other hand, the global infrastructural change brought by 5G transition has increasingly become a matter of national security, the so-called "5G war" (Frieden, 2020). Nations across the world increasingly highlight the security issue in their 5G policies. For example, infrastructure manufactures like Huawei are responsible for setting distributed base stations to connect everything, and therefore gain some control over domestic telecommunication operators. Now they have an even more important role in 5G, where the convergence of mobile networks and applications increase the penetration and the control of the infrastructure. In facing the potential geopolitical risks, the national security concern became a new raison d'être for protectionism. The EU has issued Cybersecurity of 5G networks, the EU toolbox of risk-mitigating measures, and the U.S. has issued the Secure 5G and Beyond Act of 2020 to exercise its right to prevent foreign firms from entering its 5G markets. For example, the U.S. government has conducted national-security investigations on Huawei since 2012.[4] The changing industrial policy may draw more attention and lead to more intervention from the state.

The second institutional change pertains to the industrial structure. Before 5G, the generic network standards dominated industrial development, so the networks operators enjoyed certain degree of monopoly power vis-à-vis their users. In 5G, since the relationship between the network and its users will be reversed, the network operators might not able to maintain their dominance in the industrial structure. For example, the R16 of 3GPP imposes industrial specifications by vertically applying 5G standards to various industries. Vertical industries might be able to form along the pipelines of network slices to provide total solutions for scenarios (Casetti et al., 2018).

2.3.3. *The niche level: IoT innovations*

As opposed to the regime level where incremental innovations most likely to take place, the niche level often acts as 'incubation rooms' for radical innovations (Schot, 1998), which have the potential to challenge the status quo if thrive. In other words, the regime represents a relatively stable evolutionary structure, while the niche breeds the seeds for revolution.

Before 5G, the succession of mobile communication technologies basically followed an evolutionary trajectory. From the 1G to 4G eras, the goal was to connect people with more bandwidth, more services, greater capacity, and faster speed. However, in the 5G era, the goal goes

[4] U.S. House of Representatives 112th Congress (2012), "Investigative Report on the U.S. National Security Issues Posed by Chinese Telecommunications Companies Huawei and ZTE". Retrieved from https://stacks.stanford.edu/file/druid:rm226yb7473/Huawei-ZTE%20Investigative%20Report%20(FINAL).pdf, last visited on June 17, 2022.

beyond connecting people to connecting everything to realize the ubiquitous "5G networked society" - all connectivity of people, things, data, applications, transport systems and cities in smart networked communication environments.[5] In specific, the main scenarios of 5G, eMTC and urLLC are mainly designed for the demands of IoT. Therefore, in 5G transition, it will be IoT that serves as the revolutionary seed for change.

IoT has extended the scope of mobile communications services from interpersonal communications to smart interconnection between things and between people and things, allowing mobile communications technologies to penetrate into broader industries and fields (Liu and Jiang, 2016). The sheer number of IoT devices has fundamentally challenged the ubiquitous information transmissions through the backbone networks, such as traditional cellular systems (Tello-Oquendo et al., 2018). However, compared with incremental innovations in the traditional mobile communication industry, IoT innovations are still immature and inferior in terms of performance, functionality, and cost effectiveness. So at least in the beginning, IoT innovations still need certain degree of protection from the niche level, which might make selection criteria very different from the regime, and hence open room for radical innovations.

3. Research methods

3.1. Case study

Case study has been frequently used for analyzing technological transition where single study is used for illustrating transition processes and multiple cases are usually used for comparing technological transition pathways (Geels and Kemp, 2007). In this paper, we choose China as a case to illustrate transition processes brought by 5G. The case sampling is based on the criteria of the influential case (Seawright and Gerring, 2008) since China as an aggressive promoter of 5G has a disproportionate amount of influence over the issues regarding 5G transition. In addition, country cases allow us to explore more interactions between technology and economy where policy plays an important role (Geels and Schot, 2007; Rogge et al., 2020).

In the global level, China has shown a full participation in 5G's standard-setting. China's telecom operators such as China Mobile, telecom equipment manufacturers such as Huawei and ZTE, chip manufacturers such as Spreadtrum, and terminal manufacturers such as OPPO and VIVO, all have submitted many technical proposals to 3GPP. In the national level, China has put 5G as a national priority and targeted the digital transformation and connectivity of the economy as national development strategies. The China Communications Standards Association (CCSA) and Standardization Administration of China (SAC) are responsible for the adoption of international telecommunications standards as national standards. Besides, the Chinese government issued the 5G license on June 6, 2019.[6] By the end of 2021, China has the world's largest 5G network, where the number of 5G base stations reached 1.4 billion, accounting for more than 60 % of the world's total.[7] The leading development of 5G commercialization, standardization and the comprehensive participation of China's stakeholders in the 5G construction have made China an appropriate and influential case to uncover the transition processes across the three levels of 5G transition.

3.2. Data collection and analysis

We use primary and secondary data to explore how transition processes are triggered and aligned in 5G transition in China. Table 2 summarizes the primary and secondary data structure for this paper. The primary data consists of in-depth interviews with three standard-setting experts, three patent operation experts, and two 5G researchers from China's information and communication technologies (ICT) industry. Some of the interviewees ever worked for Huawei, a leading company that has played an important role in all the three levels. Some have been active in the ICT industry for more than 10 years. They shared their insights on China's 5G industry development, the changing industry structure, major competition framework, and changing policy framework. They also recalled and shared their experiences in participating in the events on 5G standard setting, patenting and development.

For secondary data, we rely on content analysis to explore the social-technical changes in 5G transition. As for technology data, we collect patent and technical documents regarding the standard setting of mobile communication networks. The standard-setting data includes technical proposals and liaison statements drafted by 3GPP member firms. A firm can declare its patents as standard-essential patents (SEPs) to standard setting organizations once its technical solutions have been adopted by technical specifications of standard setting. By putting SEPs from leading firms together, it is possible to delineate the technological trajectory of the entire industry. As for market data, we collect the data from a variety of sources, including the agreements and contracts among governments, firms and research institutions; industry and policy white papers; and news and reports from the media. As for policy data, we collect 49 policy documents issued by China's 21 provincial governments and 4 municipalities. We use discourse analysis and latent Dirichlet allocation (LDA) to identify the policy concerns of China's 5G transition. The LDA model developed by Blei et al. (2003) has been widely used in content analysis as well as discourse analysis.

We follow the qualitative data analysis method (Carney, 1990; Miles et al., 2018) to code the collected data to trace changes across the three levels of 5G transition. As for the open coding, we firstly identify the main activities in the three levels, including 5G standard-setting in the global level, IoT innovations in the niche level, and policy and industrial

Table 2
Data structure of empirical analyses.

Research themes		Primary data	Secondary data
Social-technical regime	Policy changes	In-depth interview form experts ever worked both in ICT and IoT industry	Policy documents of 5G from China's governments • White papers • Technical specifications of standard setting • Media reports Governments reports • Huawei's annual reports Published contract information of 5G and IoT
	Industrial changes	In-depth interview from experts ever worked both in ICT and IoT industry	
Niche innovation in 5G development		In-depth interview from experts in standard setting of 3GPP In-depth interview from experts in telecommunication firms, internet firms, and IoT firms	Technical specifications of standard setting • Patent data • Technical proposals in 3GPP • Public contract information • White papers and media news

[5] ITU, "5G - Fifth generation of mobile technologies." Retrieved from https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx, last visited on April 15, 2022.

[6] "China grants 5G licenses for commercial use, starting new era in telecom industry." Retrieved from http://www.xinhuanet.com/english/2019-06/06/c_138121387.htm, last visited on March 17, 2021.

[7] Ministry of Industry and Information Technology of China (MIIT), "2021 Statistical Gazette of the Telecommunication Industry." Retrieved from https://www.miit.gov.cn/gxsj/tjfx/txy/art/2022/art_e8b64ba8f29d4ce18a1003c4f4d88234.html, last visited on April 11, 2022.

changes in the national level. Based on the open coding, we then proceed to the thematic coding to abstract the characteristics of changes in each level. With the selective coding, we finally capture the emerging patterns and make linkages across the three levels to show the alignment or misalignment of transition processes.

4. Case study: 5G transition in China

How does 5G induce the regime change in China? is the question to be investigated and answered in the case study. We begin with investigating changes in the global level, particularly those around 5G standard-setting. We then see how 5G as a trigger brings about transition processes in the other two levels: 1) niche creation in the niche level; and 2) regime reconfiguration in the regime level. We also observe the alignment or misalignment of these processes within and across the three levels.

4.1. The global level: 5G standard setting as a transition trigger

In Geels' (2005) MLP framework, landscape changes comprise: (a) relatively slow changes, for example, cultural and demographic changes, and changes in political cultures and ideologies; and (b) relatively rapid developments, war, oil prices and economic depression in social structure. We take the international standard setting of 5G as a trigger since standard setting is a technological activity in a relatively short time.

Among international SDOs, 3GPP is responsible for publishing the technical specifications of 5G promoted by ITU. Members of the 3GPP, who are usually official organizations of countries and leading firms, will discuss and build consensus in the meetings to form the technical specifications of 3GPP. The international setting of 3GPP provides network solutions, technical specifications of telecommunications equipment, and terminals through the discussion and election of the technical proposals advocated by individual members.[8] In the 3GPP RAN plenary meeting, Balazs Berteny, the chairperson, wrote that "we need to maximize the economies of scale around 3GPP's 5G radio and system standards, redefining all industries through a single platform for all connectivity applications."[9] The global 5G standard development promotes the support of IoT usage and deployment scenario – Internet of Everything (IoE) – as its main direction. The 3GPP technical specifications define the usage scenario and deployment scenario of connecting people, things, and their interconnection scenarios:

> This subsection briefly introduces the three usage scenarios defined by ITU-R IMT for 2020 and beyond… enhanced Mobile BroadBand (eMBB), massive Machine Type Communications (mMTC), Ultra-Reliable and Low Latency Communications (URLLC)... and 6.1 Deployment scenarios for [SUPPORTING] Usage scenarios.[10]

The standard setting procedures of 5G show that firms as 3GPP individual members mainly set and promote the 5G standards through making their technical proposals adopted by technical specifications. For example, the Chinese telecommunication manufacturer Huawei has actively participated in the standard-setting process by providing technical proposals to 3GPP and filing SEPs. According to European Telecommunications Standards Institute (ETSI)'s latest statistics, Huawei holds 20 % of the world's total 5G SEPs declared to ETSI.[11] The Global Data report has also stated that, "Huawei's 5G RAN portfolio holds the strongest position overall, with leading claims in all four criteria categories, including superior baseband unit capacity and radio unit portfolio breadth."[12]

4.2. The niche level: IoT innovations as novelties

In the MLP framework, novelties emerge in technological and/or market niches, which are supposed to be protected and reinforced for driving the technological transition (Geels, 2005). In 5G transition, IoT innovations are regarded as novelties, which emerge both in technological and market niches. We can take the construction of Radio Access Network (RAN) as an example, since RAN dominates the traditional standard setting from 2G to 4G. The RAN development in 5G may intensively present the departure from its predecessors' generic to a differentiated model and thereby create technological and market niches for IoT innovations.

Technical specifications of RAN comprise the functions and requirements regarding radio layers, protocols, interfaces of the radio performance, network architecture, as well as the operation and management requirements. Before 5G, it was one-size-fits-all, so all usages and applications had to comply with the same RAN specifications. But in the 5G era, business requirements and application scenarios are so diversified that RAN has to be "sliced" to meet the requirements of various IoT scenarios. A slice of the customized end-to-end logical network requires the support across RAN, transport network, core network, and management system. The Release 15 of 3GPP has thus defined the functions and procedures of network slicing in RAN, which will cut the protocol stack and time-frequency resources accordingly.

In China, the patenting and standardization activities of leading firms have played an initial role in protecting and promoting the niches for IoT innovations across multiple levels. For example, Huawei took the largest share of SEPs declared to 3GPP from 2G to 5G.[13] To protect IoT innovations, Huawei has claimed that its SEP licensing coverage would be extended to IoT, although it has already a royalty cap of 2.5 U.S.

Table 3
The top five firms' 5G RAN SEPs declared before ETSI.[a]

Declaring company	RAN1	RAN2	RAN3	RAN4
Huawei	3725	3219	777	1608
ZTE	2030	2147	433	21
Lg Electronics	2288	1863	62	23
Samsung Electronics	1479	1641	77	6
Qualcomm	2061	1029	54	59

[a] The patent is found on the website https://app.patentcloud.com/sep on March 10, 2021.

[8] GSMA (2018), "Road to 5G: Introduction and Migration." Retrieved from https://www.gsma.com/futurenetworks/wp-content/uploads/2018/04/Road-to-5G-Introduction-and-Migration_FINAL.pdf, last visited on June 17, 2022.

[9] Bertenyi, "5G Standards leadership – beyond the numbers." Retrieved from https://www.bell-labs.com/var/articles/5g-standards-leadership-beyond-numbers/, last visited on March 17, 2021.

[10] ETSI (2017) "5G; Study on scenarios and requirements for next generation access technologies." Retrieved from https://www.etsi.org/deliver/etsi_tr/138900_138999/138913/14.02.00_60/tr_138913v140200p.pdf, last visited on June 17, 2022.

[11] "Huawei White Paper on Innovation and Intellectual Property." Retrieved from https://www.huawei.com/en/industry-insights/innovation/huawei-white-paper-on-innovation-and-intellectual-property, last visited on March 17, 2021.

[12] "Telecom Industry's First 5G RAN Competitive Analysis Published by GlobalData Reveals Huawei Leadership." Retrieved from https://www.globenewswire.com/news-release/2019/07/02/1877047/0/en/Telecom-Industry-s-First-5G-RAN-Competitive-Analysis-Published-by-GlobalData-Reveals-Huawei-Leadership.html, last visited on March 17, 2021.

[13] The patent data are searched from the database "patent could" https://app.patentcloud.com/ as of October 15, 2020.

dollars on cell phones.[14] Table 3 shows that Huawei maintains its RAN technology advantage in the standard setting.

Prior to the patent and standard setting protection, as some interviewees acknowledged, novelties of IoT innovations might occur inside of the leading firms. For example, Huawei has created a 5G topic group, and some of IoT inventors may come from different R&D departments of Huawei. They may participate in standard setting activities as well. The engineers in the standard development departments also needed to file patent applications before attending standard-setting activities. This intendedly and unintendedly, helped develop, promote and protect the development of novelties.

Among the leading firms in China's mobile communication industry, Huawei might be the most prominent "visible hand" behind IoT innovations. It generally pursues four strategies to support IoT innovations. The first is through market development. The development of RAN products is a good example. From 2G to 4G, the core product of RAN was the base station with the network-centered mode. In 5G, this network-centered mode may shift to a user-centered one in order to realize the three scenarios defined by 5G. By developing RAN products for 5G, firms might be able to combine business intent and advanced technology to support IoT scenarios, and by so doing, create market niches for IoT innovations. For example, following the technical standards of 5G, Huawei has launched 5G base station, the "Single RAN Pro", which can support 5G scenarios and thereby open markets for IoT innovations.[15]

The second strategy is to promote product concepts that can support IoT innovations. For example, at the 2018 Global Mobile Broadband Forum, Huawei released its "Open Site" construction concept.[16] This concept provides modular equipment, componentized supporting equipment, and open physical interfaces to enable telecom operators to start sites for the operation of 5G. Huawei also proposes the "End-to-End (E2E) slicing solution" concept for the 5G RAN construction as well as the "5G Ultra-Lean Site" concept for constructing a whole 5G network. The latter integrates a lot of Huawei's solutions on flexible resource sharing, including LTE, 5G NR (CloudAIR), 5G spectrum efficiency (SuperBand), SingleRAN Pro, 5G Power, 5G Microwave, and antenna. In other words, it integrates as much solutions and resources as possible to support the scenario and flexible deployment of 5G.

The third is to collaborate with governments for planning and implementing their digital transformation or digital city projects, which can also help boost IoT innovations. In the traditional network paradigm, the collaboration mainly happened between governments and the operators of mobile communication networks since governments only purchased network-related services. In 5G, the scenario-based paradigm makes possible a variety of new services and applications, which open room for collaboration between governments and new service providers. For example, Huawei and the Shenzhen government have jointly issued a white paper, titled "Shenzhen Intelligent Twins: White Paper of City Security Development" in 2020.[17] Besides, Huawei also collaborate with Shenzhen to establish a digital government, and with Zhangjiakou to build a smart city, to provide customized services and solutions for them.

The fourth is to team up with partners from vertical industries for supporting IoT scenarios. Based on 5G technologies, Huawei has teamed up with several industrial partners to integrate terminal equipment, data management, and industry applications vertically to provide total solutions for IoT scenarios. For example, by using Huawei's "Horizon Digital Platform", Shenzhen Airport plans to provide scenario-based one-stop services. Scenario-based solutions will help create an airport with high efficiency, safety, and excellent experience for customers.[18]

4.3. The national level: regime reconfiguration

As an early adopter of 3GPP's 5G technical specifications, China has been aggressively pushing the commercialization of 5G. Both the scenario-based standard setting of 5G from the global level, and the incubation of IoT innovations from the niche level, have set in motion changes towards the regime reconfiguration. On the one hand, the scenario-based standard setting of 5G keeps on opening window of opportunity to create and protect niches for IoT innovations. And on the other, IoT innovations may break out of their niches when new markets arise and thrive to challenge the status quo. The ongoing processes both in the global and the niche levels continue exerting pressure on the regime, forcing the regime to change, particularly in policy and industry areas.

4.3.1. Policy changes: from central planning to local implementation

In the MLP framework, the regime is consisted of rules of policy, science, technology, industry, markets and culture, which are "the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011). In a statist country like China, among the rules in the regime, policy is no doubt the most crucial one because it represents national interests, with which it can command and sometimes even overwrite other rules (Nolan, 2001). Particularly in a highly regulated industry like mobile communication, government policies have played a critical role in building the network infrastructure, nurturing national champions, and regulate the development of markets (Gao, 2014; Kim et al., 2020; Vialle et al., 2012).

To 5G, the Chinese government has attached a great importance from the outset. It has established the IMT-2020 (5G) Promotion Group in February 2013 by three pillar ministries, namely the Ministry of Industry and Information Technology of China (MIIT), the National Development and Reform Commission of China (NDRC), and the Ministry of Science and Technology of China (MOST), to supervise the formulation of 5G standards and the promotion of 5G commercialization.[19] The development of 5G has been also transcribed into China's "Thirteenth Five-Year Plan Outline," "Thirteenth Five-Year National Informatization Plan," "National Informatization Development Strategy Outline," "Information Communication Industry Development Plan (2016–2020)," and other policy documents. China's local governments have also released a flurry of development policies with 5G network construction goals, commercialization roadmaps, and timetables.

Some studies have explored China's policy concern in the 3G and 4G eras (Liu and Jayakar, 2012; Xia, 2011; Yu et al., 2012). The policy focus on 3G was the indigenous innovation because at that time China lacked either adequate technological-push or demand-pull for full-scale

[14] "Huawei releases white paper on innovation and intellectual property 2020." Retrieved from https://www.huawei.com/en/news/2021/3/huawei-releases-whitepaper-innovation-intellectual-property-2020, last visited on March 17, 2021.

[15] Edward Deng, "SingleRAN Pro enables simplified target networks in the 5G era, leading the MBB industry to new heights." Retrieved from https://www.huawei.com/en/technology-insights/publications/huawei-tech/87/singleran-pro-enables-5g-era-simplified-target-network, last visited on September 17, 2021.

[16] "Huawei-release-open-site-solution" (In Chinese). Retrieved from https://www.huawei.com/cn/news/2018/11/huawei-release-open-site-solution, last visited on September 17, 2021.

[17] "Huawei Announces Intelligent Twins and Works with Partners for All-Scenario Intelligence." Retrieved from https://www.huawei.com/en/news/2020/9/huawei-intelligent-partners-all-scenario-intelligence, last visited on March 17, 2021.

[18] "Improving the experience: Shenzhen airport evolves intelligence with the Huawei Horizon Digital Platform." Retrieved from https://e.huawei.com/en/case-studies/leading-new-ict/digital-city/shenzhen-airport, last visited on March 17, 2021.

[19] "Structure of IMT-2020 (5G) Promotion Group." Retrieved from http://www.imt2020.org.cn/en/category/65573, last visited on March 17, 2021.

commercialization (Xia, 2011); while on 4G was standard diffusion (Yu et al., 2012). To explore the 5G policy concern, we use content analysis (Bowen, 2009) to conduct a topic modelling on a variety of policy documents. Table 4 summarizes the resulting six main topics, including commercialization, digitalization, infrastructure construction, computing, smart city, and coverage. Among the six topics, three of them, commercialization, infrastructure, and coverage, are more associated with the construction of the network, while the other three, digitalization, computing, and smart city, are more associated with the construction of scenarios. This suggests a shift on policy concern from indigenous innovation of 3G, standard diffusion of 4G, to the construction of the network and scenarios of 5G.

Besides the central government, local governments also have a stake in policy making and implementation. On the one hand, China's regulations over the mobile communication generally follow a hierarchical structure where the MIIT formulates policies in national level while local governments are responsible for implementation and enforcement of these policies in the local level. But on the other hand, local governments have the de facto power in controlling and regulating the development of the mobile communication network as well as industry.

During 3G and 4G eras, even in the early stage of promotion, local governments tended to pass on the responsibility of policy implementation to the operators. Just like an interviewee who worked in one of the major operators said: "*The government will not tell us how many base stations we should set and we may even construct 4G network when 3G is promoting*." But in 5G, local governments start to take the responsibility on the construction and implementation of the network. For example, many local governments have issued 5G policy documents, in which they have set the number of 5G base stations and 5G experimental scenario sites as policy targets. This resonates with the call from Premier Keqiang Li. In his government work report delivered at the Third Session of the 13th National People's Congress of the PRC, he proposed "new types of infrastructure" ("*Xin Jijian*") to strengthen the development of China's 5G and to develop a new generation of information network construction distinguished by "expanded 5G applications."[20]

Therefore, from 3G, 4G to 5G eras, China's policy environment on mobile communication has undergone a qualitative change (Table 5).

Table 4
The topics and top words of China's 5G policy documents.

Topics	Top words
Commercialization	Intelligentization, Intellectual Property, Production Activity, Radio Frequency, Indigenous, Telecom Operators, High-end, Types of Operation, Experiments
Digitalization	Ministry of Science & Technology, Intelligentization, Software, Industrialization, Agglomeration, Network Safety, Intelligent Network, Key Technology, Scenic Area, Digitization
Infrastructure Construction	Communication Network, Highway, Public Utilities, Public Resources, Construction, Transportation, Ministry of Construction, Local Government, Railway, Environmental Protection
Computing	Internet Industry, Industrial Park, Monitor, Backbone Enterprise, Entrepreneurship, Security, Broadcasting, Rail, Creativity
Smart City	Transportation Bureau, Intelligentization, Interconnection, High Quality, Transportation, Radio & Television Administration, Fund, Governance, Digitization, Venue
Coverage	Radio & Television, Broadband, China Telecom, Bandwidth, Information Center, Community, Procurement, Optical Fiber, Building

Besides a shift on the policy concern, there is also a shift on the role of local governments from passive supervisors to active implementers. Local governments begin to pay a greater attention to the implementation of 5G and the demonstration of 5G scenarios. Therefore, it will be local governments, not telecommunication operators, that dominate the commercialization and implementation of China's 5G. As a consequence, local governments also have to take the responsibility of security concern, which is more significant in the 5G era.

4.3.2. Industrial changes: from oligopoly to diversification

5G transition has also led to changes in the industrial structure in the regime level. In the 2G to 4G eras, the generic network standards guided industrial development, so it was generally the operators that dominated network construction and industry development (Kwak and Lee, 2012). However, in the 5G era, network slicing will allow firms from both vertical and horizontal industries to participate in the construction of the network and scenarios, so it is expected that the operators will lose their dominant positions sooner or later.

In China, the dominance of the three traditional mobile communication operators, namely China Mobile, China Unicom, and China Telecom, has already been shaken. The central government has made a comprehensive plan for the development of 5G, and invited a variety of stakeholders to participate, including local governments, operators, and leading firms from both vertical and horizontal industries. The central government meant to weaken the dominance of the operators, and promote a more diversified industrial structure. For example, in the construction of 5G networks, in addition to the three operators, the central government also issued a 5G license to China Broadcasting Network Corp Ltd. (CBN). The license grants CBN the right to use a frequency band for data communication among 5G internet providers. The central government also initiated the establishment of the China Tower Corporation Limited (China Tower), which will build 5G base stations side by side with the three operators. According to the MIIT, by March 2020, China had built 198,000 5G base stations, more than any other country in the world.[21]

Besides governments, private firms also play an increasingly important role in diversifying the industrial structure. In contrast to the 3G and 4G eras where the operators monopolized the network business, in the 5G era, private firms may engage in head to head competition with the operators. For example, in order to meet the requirements of scenarios, some leading firms from the mobile communication industry and vertical industries begin to operate their private enterprise networks. Particularly in industrial IoT (IIoT) scenarios, they can apply for the operation license to build and run private networks for industrial users. As more and more private firms join the competition, there will be two consequences. On the one hand, the boundaries of firms in the one-size-fits-all network paradigm will be blurred, and on the other, more room will be created for niche innovations on scenarios.

5. Conclusion and discussion

Through the case study, we analyze changes in the three levels during 5G transition, which suggest: 1) 5G standard-setting as a transition trigger in the global level; 2) IoT incubation in the niche level; and 3) regime reconfiguration in the national level. These changes, however, must be put under the scrutiny of alignment to make linkages between them. According to Kemp et al. (2001), "It is the alignment of developments (successful processes within the niche reinforced by changes at regime level and at the level of the sociotechnical landscape) which determine if a regime shift will occur". The alignment is important for

[20] "Full Text: Report on the Work of the Government." Retrieved from http://english.www.gov.cn/premier/news/202005/30/content_WS5ed197f3c6d0b3f0e94990da.html, last visited on March 17, 2021.

[21] "China has built 198,000 5G base stations, covering 50 million users." Retrieved from https://news.cgtn.com/news/2020-05-03/China-has-built-198-000-5G-base-stations-covering-50-million-users-Qc6vF1lXOM/index.html, last visited on March 17, 2021.

Table 5
The changing policy environment.

	3G	4G	5G
Policy concern	Indigenous innovation	Standard diffusion	Construction of the network and scenarios
Policy maker	MIIT	MIIT	IMT-2020 (5G) Promotion Group
Role of local governments	Supervision of policy implementation	Supervision of policy implementation	Policy implementation
Security issues	Not specially highlighted	Not specially highlighted	Security concern of devices, networks and vertical industries

stability and sustainability of both regime reconfiguration and actors' construction and response. Therefore, we can observe how this alignment helps reinforce regime reconfiguration and stabilize a new regime.

Fig. 2 shows the alignment analysis of this case study. We begin with 5G standard-setting at the global level to align interest groups within SDOs, particularly leading firms from China. The inclusion of IoT into 5G standards triggers transition both at the niche and the regime levels. At the niche level, 5G standards will create a technological niche for IoT innovations since two of three main scenarios promoted by 5G, eMTC and urLLC, are primarily designed for the demands of IoT. Leading firms from China also help create a market niche for IoT innovations by promoting 5G standards as well as scenario-related product concepts in China. With the protection of these two niches, new markets and industries are excepted to emerge over time, which might have the potential to challenge the status quo, the regime. At the regime level, transition pressures come from two directions: 5G standard-setting from the global level and radical innovations from the niche level. To respond to the former, the regime in China redirects its policy and restructures its industrial structure towards 5G; while to the latter, it puts more emphases on the promotion and development of IoT-related investment and initiatives to help incubate IoT innovations.

However, because 5G transition is still in its early stages, more investigation is needed to explore the interaction and dynamics within and between levels. At the regime level, it is still not clear the underlying processes and mechanisms drive reconfiguration: what are they? do they have any contradictions and conflicts? how far and how broad can reconfiguration go? how would the new regime influence contextual developments in the landscape? At the niche level, more attention should be paid to the emergence, survival and development of novelties: what types of novelties really emerge? how will new markets and industries develop around these novelties? how will they challenge the status quo? (Fig. 3).

In this paper, we adopt Geels' (2002) MLP to propose an appreciate framework for exploring the technological transition brought by 5G. Compared with the network-based view, the adoption of MLP has three merits. Above all, it brings in more interactions and dynamics between technology and economy. By so doing, we are better to broaden the scope of the network-based view on 5G, which has been too narrowly defined by standardization. In addition, the multiple-level investigation helps shed light on regime reconfiguration, which provides a selection mechanism for actors to interact and coevolve with their environment. Finally, the multiple-level investigation helps evaluate the actors' responses by observing how they align or misalign with the directions of changes during reconfiguration, which is important for stability and sustainability of both regime configuration and firm transformation.

Compared to the previous works on MLP, the adoption of MLP in this paper also has two potential contributions. One is that it might extend the scope of MLP studies from mainly focusing on sustainability in energy to the convergence in mobile communication. As Geels (2019), the inventor and advocate of MLP, acceded, prior MLP studies have been too concentrated on sustainability transitions, especially about energy technologies. Sustainability transitions concern reducing the risk of energy depletion through governance, while convergence transitions in mobile communication concern all connectivity of people, things and everything. The technological trajectories and technical standards towards convergence are totally different from those of sustainability, so they will have different implications on theories as well as practices. The other is that we provide an ongoing transition case instead of a historical case. In the review of Geels' research, Johan Schot proposed that "It is an invitation to make the next step: from doing individual case studies and developing piecemeal insights to seeking a deeper understanding of patterns in the direction and processes of technological transitions span 50 to 100 years" (Geels, 2005). The 5G transition might be the one.

Furthermore, the appreciative framework proposed in this paper has the potential for application, not only technological transitions that are driven by standard-setting, but also the ones in highly regulated

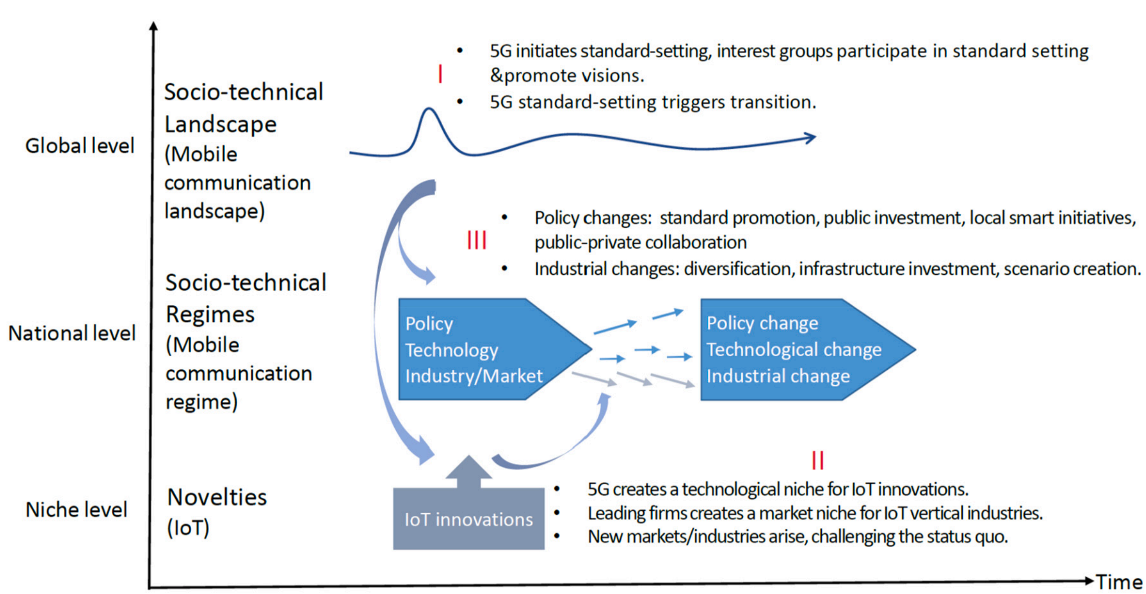

Fig. 3. The MLP analysis of 5G transition in China.

industries where technological changes are guided by regulatory bodies either at the national level or the global level. The integration of MLP offers a more comprehensive framework to take into accounts the contextual changes, which are critical when sea changes in the society challenge the socio-technical structure. For example, COVID-19 has accelerated vaccine development and reshaped the relationship between regulators and the regulated. New biopharmaceuticals like BioNTech and Moderna now seem to have more power to influence the technological transition brought by mRNA, including the vaccination process and the regulatory system. We are looking forward to seeing more work that is based on MLP through different lenses and from different technological areas.

CRediT authorship contribution statement

Chuan-Kai Lee: Conceptualization Ideas; Investigation; Methodology Development; Formal Analysis; Writing - Review & Editing; Project Administration; Supervision.

Limeng Yu: Investigation; Methodology Development; Formal Analysis; Writing- Original Draft.

Declaration of competing interest

None.

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