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by

Martin Nielsen

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Department of Business and Economics
Faculty of Business and Social Sciences
University of Southern Denmark
Campusvej 55, DK-5230 Odense M
Denmark

E-mail: lho@sam.sdu.dk / http://www.sdu.dk/ivoe

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Abstract

This paper analyzes the way payments by content providers to an Internet service provider may affect investment in Internet speed and content quality. It derives payment mechanisms capable of aligning investment incentives between the two groups; in fact, some of them are Pareto-improving also for consumers, who are willing to pay for quality of content. On the other hand, some parameter combinations may require public intervention for Pareto improvement to be attained.

Keywords: Internet regulation, Network neutrality, Investment Incentives, Monopoly, Duopoly, Regulation, Internet content, Netflix, Internet Service Providers, AT&T, Verizon, Comcast

JEL classification: L1, D4, D42, D43, C72, L12, L13, L14

*Department of Business and Economics, University of Southern Denmark, Campusvej 55, DK-5230 Odense M, Denmark, Email: mart@sam.sdu.dk

1 Introduction

From March 2014 to February 2015, some Internet users in the United States would experience faster and more reliable Internet speed when visiting Netflix.com than when visiting any other website. Netflix paid so-called last-mile fees to two Internet service providers (ISPs), Comcast and Verizon, for priority on their networks following a period of time during which the ISPs had slowed down content from Netflix. The agreement caused an uproar, where for example Barack Obama stated that "ISPs should not restrict the best access or pick winners and losers in the online market place for services and ideas." On the other hand, the ISPs claim that a side effect of Netflixs popularity is that it overwhelms their networks. On February 26th, 2015, the Federal Communications Commission (FCC) in the United States adopted a set of rules that prohibits ISPs from prioritizing Internet traffic from some content providers (websites) over others. The Netflix deals were abolished.

The policy focus on the prioritization aspect of last-mile fees has implied that an important issue has been sidelined: How do last-mile fees affect the quality investments on the Internet? This article addresses this question by focusing on the strategic interaction between access and content providers. Users obtain utility from internet use based on a combination of their access quality (speed) and the amount of content available and its quality. For the user experience, access and content quality are highly complementary. For example, high-speed Internet access is redundant for streaming movies on Netflix if these movies can only be streamed in a low resolution. Conversely, having high-definition videos available on Netflix does not provide much utility with a poor Internet access that cannot support it. By analyzing the impact of last-mile fees on the incentives to invest in access and content quality respectively, the article provides a different perspective to the more broad question on the impact of last-mile fees.

Analyzing a simple three-stage game (last-mile fee contracting, investment, access pricing), this article considers a setting where one access provider A and one representative content provider C strategically decide upon the quality of their service. The article finds that last-mile fees can be used as a transfer from content providers to the ISP, increasing ISP investment in their access quality. In this way, C can overcome a situation where their investment in quality is rendered worthless by low access quality. In fact, it is found that in such a situation there exist last-mile fees that are Pareto-improving. However, the contractual set-up behind a fee matters as, if the fee is determined by the ISP, the ISP may find it profitable to charge a fee that reduces content quality compared to a situation without fees.

The article is a contribution to the economic literature on net neutrality which is a new strand of literature. The literature has primarily been concerned about the effects of last-mile fees, prioritization of contents, and price discrimination, a recent survey can be found in Krämer et al. (2013).

Choi and Kim (2010) focus on what the prioritization aspect of network neutrality means for the investment incentives. They set up a model based on queuing theory to accommodate the need for rationing due to the scarce bandwidth. Their results indicate that if the quality and investment costs are sufficiently similar across content providers, net neutrality is better from a welfare perspective. The authors find that deviating from network neutrality will not necessarily make access providers invest in access quality. Interestingly, while their study focuses on prioritization, and the present model focus on last-mile fees, we get the same result: it may actually harm the quality of the Internet if the access providers decides the terms. Hence, the present model complements their work.

Several papers consider the access provider as a platform allowing interaction between users and content providers in a two-sided market setting (see for example Rochet and Tirole, 2006; Rysman, 2009, for surveys on two-sided markets). For example, Economides and Tåg (2012) extend the seminal two-sided market model of Armstrong (2006) to analyze the effect of one-sided (net neutrality) vs. two-sided pricing on the number of users and content providers. Basically, welfare enters their model through cross network effects between the group of users and the group of content providers. By comparing the number of participants in each group when the access provider - as a platform - is restricted to only charge users instead of both users and content providers, the authors show which scenario yields the highest welfare coming from cross network effects. In the present model utility does not come from the number of content providers but rather from the quality of the content that is available and to the extent that it is supported by the access quality.

Lee and Wu (2009) provide an interesting discussion on the pros and cons of payments from content to access providers. Among other things, they argue that banning last-mile fees may be interpreted as a policy that provides a subsidy to content creation and provision. This interpretation is in line with the results of the present model. However, the present model suggests that at the current moment, the Internet as a whole does not call for stronger incentives to develop content quality, but for stronger incentives to develop access quality.

As was the case in Choi and Kim (2010), Cheng et al. (2011) also consider the investment incentives where the number of users cause the congestion problem. In contrast, the present model considers another channel leading to congestion, namely content quality. For the given Internet access quality and number of Internet users of today, if the content available on the Internet was that of 15 years ago, there would hardly be a problem of congestion. Hence, we believe that the development of applications on the Internet and the increased quality of those applications is just as important as the number of users. Similar thoughts are presented in Economides and Hermalin (2012). In their model, they let the demand for content from a given content provider vary, so that stronger bandwidth will attract more traffic.

The present paper adds to the current literature on net neutrality by analyzing the strategic interaction between access and content providers when deciding to invest in the quality of their service. In particular, some last-mile fees are shown to align investment incentives between the two groups and lead to Pareto-improvement, also for users.

The article is structured as follows. Section 2 is the model section, introducing Internet users as well as the access and content providers. Interaction between access and content providers follows three stages, each having their own section. Section 3 analyzes the stage of pricing of Internet access. Section 4 analyzes the investment stage. Section 5 analyzes the welfare implications of last-mile fees from the contracting stage. Finally, in section 6 the role of investment costs for the access provider is highlighted. Section 7 offers a summary and concluding remarks.

2 The Model

Consider a mass of potential Internet users deciding whether or not to purchase access to the Internet. Their willingness to pay for access is a function of access quality, q_A, and content quality, q_C. Access quality is the speed of the Internet connection. Content quality summarizes the amount of content that is available on the Internet and the quality of their supply. Improved access quality only results in a better Internet experience for users if this is required by q_C. Conversely, improvements in q_C results in higher utility for users if it is supported by a concomitant increase in q_A. A function that captures this Leontiff-type perfect complementarity is $\min\{q_A, q_C\}$. A Leontiff-type function to analyze perfect quality complementarity was also used by Economides (1999), although in a different set-up.

Generally, increased Internet usage could stem from existing subscribers increasing their usage or increased number of subscriptions. While the former effect is also important, for simplicity, this article only models the latter. Hence, suppose that each potential user has unit demand for a bundle comprising access and one unit of content. Further, let the access provider set just one level of quality q_A. This simplification can be justified by the fact that users do not have a choice of Internet speed when there are bandwidth problems. For example, even users paying for high-speed Internet ended up with an inferior stream from Netflix before March 2014 where Netflix struck a deal with Comcast.

Individuals differ with respect to their willingness to pay for access to the Internet and its content. Regardless of the access and content quality, some individuals value the Internet more than others. Let each individual have a taste parameter $\eta \in [0, M]$ and suppose that a mass of individuals of size M has tastes distributed uniformly over this interval. Here, η symbolizes a reduced willingness to pay reflecting preference heterogeneity. Let M be sufficiently large such that some consumers prefer not to make a purchase at all. A consumer with taste $\eta \in [0, M]$ obtains net utility from purchasing Internet access at price p_A of

$$U(q_A, q_C, p_A) = \min\{q_A, q_C\} - \eta - p_A. \tag{1}$$

Assuming that only individuals with nonnegative net utility make a purchase, the number of consumers who will make a purchase equals the number of consumers with a taste satisfying $\eta \leq \min(q_A, q_B) - p_A$. Therefore, the demand function can be constructed as

$$n = \min\{q_A, q_C\} - p_A. \tag{2}$$

Content providers compete against each other and differentiate themselves on a wide range of attributes. First, different content is available for different purposes; some content providers like Amazon and Youtube maximize profits while for example Wikipedia is non-profit and has the purpose of enlightening users. Second, while much content is available for free, some content like Amazon ebooks, Netflix, and iTunes directly charge consumers. Third, some content requires a better access service than other content. Rather than focusing on the monopolistic competition between content providers, this article analyzes the interaction between the monopoly access provider and the content providers. For this purpose one representative content provider is picked.

The representative content provider receives an external benefit when the users visit their website, for example in terms of advertisement revenues. Suppose that for each user the content provider sends information to, he receives an external benefit of $\alpha > 0$ and pays a last-mile fee T to the access provider. The objective function of the content provider reads

$$\pi_C = (\alpha - T)\underbrace{(\min\{q_A, q_C\} - p_A)}_{n} - c_C q_C^2, \tag{3}$$

where q_C is the quality of the content. The investment cost function is assumed to be strictly convex to make the profit function strictly concave in quality. If the profit function was not strictly concave in quality, then the provider would either not invest in quality or invest indefinitely in quality.

The monopoly access provider earns $(p_A + T)$ per user minus investment costs:

$$\pi_A = (p_A + T)\underbrace{(\min\{q_A, q_C\} - p_A)}_{n} - c_A q_A^2. \tag{4}$$

Here, it is assumed that q_A is independent of the number of Internet users, n, and the costs of investing in quality is continuous, not lumpy. As mentioned in the introduction, the role of n on congestion has been intensively studied in the previous literature. In contrast, this study introduces congestion triggered by the quality interaction between access and content quality. Regarding the continuous investment function, we analyze how last-mile fees affect the incentives to improve the Internet quality as a whole for the two groups of providers. These incentives are most easily captured in a continuous setting and the assumption also follows the standard literature.

Ultimately, the interest of this article lies in the impact of the last-mile payment, T, and how it matters who selects it. The interaction between the access provider, A, and the content providers, C, follows three stages:

Stage 1: ***Contracting:*** The last-mile service fee, T, is selected by the access provider.[1] The paper will look at different contractual setups and see how they affect the outcome of the future stages.

[1] The article also analyzes different setups of T.

Stage 2: ***Investment:*** At the start of this stage, the contract is common knowledge. Given T, the access and the content providers simultaneously and non-cooperatively selects an investment in the quality of their services, q_A and q_C, respectively.

Stage 3: ***Pricing of access:*** At the start of this stage, the quality of the services provided by A and C is common knowledge. The access provider chooses a price that Internet users have to pay to gain access to the Internet content, p_A.

Once the price has been set, the potential Internet users decide whether or not to purchase access to the Internet. The problem of interest is determining the effect of the contract in stage 1. The game is solved by solving the stages backwards in time.

3 Analysis of the Pricing Stage

The access provider selects the consumer access price, p_A, that maximizes (4) which is strictly concave in p_A. This price is given by

$$p_A^* = \frac{\min\{q_A, q_C\} - T}{2}. \tag{5}$$

The following result is immediate:

Observation 1 *The higher the last-mile fee the access provider receives from content providers, the lower the price they will charge from consumers.*

Everything else equal, the last-mile fee raises the per user profit of the access provider without lowering the demand. Taking this into account, the access provider will attract new users by lowering the access price. Given this price, the profits of the access and content providers become

$$\pi_A = \left(\frac{\min\{q_A, q_C\} + T}{2}\right)^2 - c_A q_A^2 \tag{6}$$

and

$$\pi_C = (\alpha - T)\left(\frac{\min\{q_A, q_C\} + T}{2}\right) - c_C q_C^2, \tag{7}$$

respectively.

The aggregate consumer surplus is given by the sum of net utilities for all individuals who establish a connection. Hence,

$$CS = \int_0^{min\{q_A,q_C\}-p_A^*} U(q_A, q_C, p_A^*) d\eta = \frac{1}{2}\left(\frac{\min\{q_A, q_C\} + T}{2}\right)^2. \tag{8}$$

4 Analysis of the Investment Stage

The price that the access provider will end up charging consumers for access to the Internet and how it depends on quality are common knowledge. Given this knowledge, the content providers decides what applications to develop as well as their quality, both summarized by q_C, and the access provider decides which broadband speed and reliability to supply, summarized by q_A.

Simultaneously, the access provider maximizes (6) with respect to q_A, and the content provider maximizes (7) with respect to q_C. Recall that access quality only results in better Internet experience to the extent it is required by the content quality. Conversely, content quality only results in better Internet experience to the extent access quality supports it. Therefore, since investment in quality is costly, the following result is immediate:

Observation 2 *Neither the access provider nor the content provider will improve their quality more than the other provider.*

In particular, the access provider has a preferred level of Internet quality, q_A^p, and similarly does the content providers, q_C^p. Since the providers maximize different objectives, there may be discrepancies between their preferred levels. A result that follows immediately is

Proposition 1 *The provider preferring the smallest quality improvement of the Internet dictates the actual quality of the Internet.*

From equations (7) and (6), the profit of the content provider is strictly concave in $\min\{q_A, q_C\}$, while this is also the case for the access provider if and only if $c_A > 1/4$. For $c_A \leq 1/4$ the access provider will always prefer to have a higher quality of the Internet. This section now proceeds by analyzing the case where π_A is strictly concave in c_A. The special case where $c_A < 1/4$ is analyzed in section 6.

Maximizing π_A with respect to q_A and π_C with respect to q_C and taking Observation 2 into account, gives the following best response functions:

$$B_A(q_C) = \begin{cases} \frac{T}{4c_A - 1}, & \text{if } q_C \geq \frac{T}{4c_A-1} \\ q_C, & \text{otherwise} \end{cases} \tag{9}$$

and

$$B_C(q_A) = \begin{cases} \frac{\alpha - T}{4c_C}, & \text{if } q_A \geq \frac{\alpha - T}{4c_C} \\ q_A, & \text{otherwise} \end{cases}, \tag{10}$$

respectively.

From equation (9), the preferred level of Internet quality for the access provider is increasing in last-mile fees. The reason is that last-mile fees increase their per user profit, and thus increase their incentive to get more users on board. Observation 1 shows one channel: lowering user subscription fees. Equation (9) shows another channel: investing in a better access service. From the perspective of a content provider, on the other hand, last-mile fees decrease the per user pay-off, and hence their incentive to invest in quality decreases with T, equation (10). Inspecting the best response functions shows that they are simultaneously fulfilled if and only if

$$q_A = q_B = q^*(T) = \min\left(\underbrace{\frac{T}{4c_A - 1}}_{q_A^p}, \underbrace{\frac{\alpha - T}{4c_C}}_{q_C^p}\right). \tag{11}$$

The quality function $q^*(T)$ is the Nash equilibrium of the Stage 2 game. The first element in the min function, q_A^p, is the preferred level of quality of the access provider. The second element, q_C^p, is the preferred level of quality of the content providers. The following result applies:

Lemma 1 *For $c_A > 1/4$, if $T = 0$, then $q^* = 0$.*

A neat feature of the model, which creates simple benchmark comparisons, is that in the scenario with no last-mile fees ($T = 0$), no quality improvements take place, i.e., $T = 0$ is the status quo. One should interpret quality investments on access and content qualities as improvements from the status quo. That is, Lemma 1 simply suggests that if nothing changes with respect to the Internet as it is, i.e., demand, investment costs, etc., then the Internet quality will not be improved.

Note that in the status quo $q_C^p > 0$, meaning that content providers are ready to develop new applications or services but are discouraged because of the access provider's lack of incentive to follow up with investments in access services that support them. Interestingly, since last-mile fees provide investment incentives that go in opposite directions for the access and content providers, last-mile fees can align the investment incentives between the two parties. This is evident from the following result:

Proposition 2 *For $c_A > 1/4$, q^* is increasing in T until a specific threshold, after which q^* switches from q_A^p to q_C^p and becomes decreasing in T.*

Let $\overline{T}$ denote the last-mile fee that solves $q_A^p = q_C^p$. Then

$$\overline{T} = \frac{\alpha(4c_A - 1)}{4c_A + 4c_C - 1}. \tag{12}$$

Clearly, $T < \overline{T} \Leftrightarrow q^* = q_A^p$, and $T > \overline{T} \Leftrightarrow q^* = q_C^p$. The welfare implications of last-mile fees in case 1 will be analyzed in the next subsection.

5 Welfare implications of last-mile fees

The impact of the introduction of last-mile fees on economic welfare will now be highlighted for $T \leq \overline{T}$ and $T > \overline{T}$. Consider first $T \leq \overline{T}$. Substituting q_A^p into (6) and (2) yields

$$p_A = \frac{T(1 - 2c_A)}{4c_A - 1} \text{ and } n = \frac{c_A T^2}{4c_A - 1}. \tag{13}$$

As a benchmark, (13) shows that before last-mile fees are introduced ($T = 0$), no extra consumer price will be charged, $p_A = 0$, and no extra users will connect ($n = 0$). For a given T, substituting out (13) into the profit functions and consumer surplus yields

$$\pi_A = \frac{c_A T^2}{4c_A - 1} \tag{14}$$

$$\pi_C = (\alpha - T)\left(\frac{2c_A T}{4c_A - 1}\right) - \frac{c_C T^2}{(4c_A - 1)^2} \tag{15}$$

$$CS = \frac{2c_A^2 T^2}{(4c_A - 1)^2}. \tag{16}$$

From (14) and (16) it is easy to see that last-mile fees benefit the access provider and ultimately users as both functions are increasing in T in the interval $[0; \overline{T}]$. The effect of last-mile fees on content providers is not obvious. However, evaluating the derivative $\frac{\partial \pi_C}{\partial T}$ for $T = 0$ yields

$$\left. \frac{\partial \pi_C}{\partial T} \right|_{T=0} = \frac{2\alpha c_A}{4c_A - 1} > 0, \tag{17}$$

which is positive since $c_A > 1/4$ by assumption for this analysis. Equation (17) implies that the content providers would in fact *benefit* from subsidizing the access provider with some last-mile fees. While last-mile fees do decrease the per user pay-off, they also imply that the access provider will invest in better access quality. This allows the content providers to develop content of higher quality because these will be supported by the access service. For some last-mile fees the latter effect dominates the former. Since increasing T from $T = 0$ benefits all parties, the following result is immediate:

Proposition 3 *For $c_A > 1/4$ there exist last-mile payments that are Pareto-improving.*

Proposition 3 has important policy implications. Last-mile fees cannot only be used to prioritize a given quality between content providers as highlighted in the policy debate. Last-mile fees also affect the incentives to invest in quality. In fact, if content provider investments are held back because access providers lack incentives to follow up, then participants as a whole can benefit from unified last-mile fees.

Note, however, that the content provider does not increase profits from all increases in the last-mile fee - even in the $[0; \overline{T}]$ interval. For example, we have

$$\left. \frac{\partial \pi_C}{\partial T} \right|_{T=\overline{T}} = \frac{2\alpha[(c_A - 1)c_C - (4c_A - 1)c_A]}{(4c_A - 1)(4c_A + c_C - 1)}, \tag{18}$$

which is negative for some parameter values satisfying $c_A > 1/4$. Hence, the profit of the content provider is not necessarily increasing through the complete interval $[0; \overline{T}]$. Therefore, some parameter combinations may require public intervention for Pareto improvement to be attained. This is elaborated in section 6.

When T exceeds the threshold value $\overline{T}$, q^* switches from q_A^p to q_C^p, meaning that the content provider dictates the critical quality improvements. Equation (11) shows that q_C^p is decreasing in T and becomes zero when T reaches α. Thus, the maximum value of q^* is caused by $T = \overline{T}$. This in itself does not imply that $T = \overline{T}$ is optimal from a welfare perspective. While $q = 0$ is an underprovision of quality given that each market entity will improve welfare from the introduction of last-mile fees, there is also a potential for overprovision. The model specific optimal level of provision will depend on the weighting of different entity pay-offs against each other.

6 The role of investment costs for the access provider

The analyses in sections 4 and 5 assumed that $c_A > 1/4$. The assumption implied that content providers were held back by the lack of incentive to invest in quality coming from the access provider, i.e., $q_C^p > q_A^p$. In that scenario, without last-mile fees, new applications of higher quality on the Internet would not be developed due to lack of support by an insufficient access quality.

If the cost of providing access quality is sufficiently low, then the story is different. When $c_A \leq 1/4$, the access provider is always ready to meet whatever quality level is required by the quality supplied by content providers. The best response function of the content providers remains the same, equation (10). Therefore, the quality function becomes

$$q^*(T) = \frac{\alpha - T}{c_C}. \tag{19}$$

This quality function corresponds exactly to what the content providers consider as the preferred level of Internet quality. An important result is as follows:

Proposition 4 *When $c_A < 1/4$, the quality of the Internet is strictly decreasing in last-mile fees.*

Quality development of the Internet is a coordination game where access and content providers independently choose the quality of the services they provide. If the truth is that content providers constitute the critical bottleneck slowing down further development of the Internet, then last-mile fees will not help the progress. In fact, last-mile fees will slow down the development of Internet quality further.

An important question is whether the access provider has an incentive to accommodate last-mile fees even when it implies inferior Internet service. Substituting out (19) in (6), the stage 1 profits become

$$\pi_A = \frac{[\alpha + (4c_C - 1)T]^2 - 4c_A(\alpha - T)^2}{64c_C^2}. \tag{20}$$

Equation (20) shows that the access provider faces a trade-off between increasing demand through subsidizing ($T \leq 0$) or charging last-mile fees ($T > 0$) and hence earning more per user. Evaluating the derivative for $T = 0$ gives

$$\left.\frac{\partial \pi_A}{\partial T}\right|_{T=0} = \frac{\alpha(4c_A + 4c_C - 1)}{c_C^2}. \tag{21}$$

Hence, for $c_A < 1/4$, if c_C is sufficiently high, the access provider benefits from the introduction of last-mile fees even though they compromise Internet quality. Thus, for some parameters, if the last-mile fee is decided by the access provider, the quality of the Internet may be harmed.

7 Summary and Concluding Remarks

This article analyzed how last-mile fees affect the strategic investment situation between an access provider and content providers. Last-mile fees affect incentives to invest in quality in two opposite ways. If content providers are to pay a positive fee to the access provider for sending their content to users over their broadband lines, then they have a lower incentive to supply high-quality content, and the ISP a stronger incentive to improve their broadband lines. Therefore, given that the quality of access services and the quality of Internet content are strongly complementary, last-mile fees can work as a policy tool to align investment incentives and hence improve Internet quality if access providers are holding back content developers.

Now, consider the Netflix-ISP debate in 2013: Netflix sought to supply high-definition streaming but was initially unsuccessful because the access quality of ISPs was insufficient. Even users paying for high-speed Internet access ended up with a stream of inferior quality. Generally, content providers are ready to develop and introduce new content. However, such investment are deterred because it is not matched by the required improvements in access quality by ISPs. Hence, policy needs to focus on the incentives to improve access services of ISPs.

Last-mile fees promote investment in broadband networks that can support the quality that content providers are ready to develop. The Internet experience will be enhanced for users due to the increased Internet speed and the enhanced content that users are willing to pay for. Last-mile fees offer a means for content providers to subsidize investments in broadband services, and this study finds that content providers are better off paying *some* fees. Hence, there exist last-mile fees that are Pareto-improving for all parties concerned.

Importantly, we find that a Pareto-improving last-mile fee is not necessarily reached if the fee is determined by the ISP. In particular, this study finds that content, which does not require a stronger broadband service, may be harmed. It may be more profitable for the

ISP to strangulate content and, hence, Internet quality for the sake of increasing the revenue stream from last-mile fees. Therefore, the exact contractual relationship determining last-mile fees matters.

Yet, public policy has been focusing on last-mile fees for prioritization, meaning that a content provider can pay a fee to obtain a "fast-lane" advantage over content competitors. This study shows that last-mile fees can also be used to align investment incentives between content and access providers and promote investments in better broadband services. Hence, last-mile fees can be used to affect the size of the cake and not only its distribution.

As the development of future Internet content requires broadband services that support this content, it is essential that the Federal Communications Commission (FCC) addresses the issue of how to increase investment incentives for the ISP. While this study finds that last-mile fees can be harmful if decided by the ISP, it also shows that there exist last-mile fees that benefit all Internet participants and that the optimal last-mile fee is positive, not zero. The FCC has adopted a set of rules that prohibits ISPs from prioritizing Internet traffic from some content providers over Internet traffic from others, but they may consider adopting a set of regulated last-mile fees to accelerate Internet development.

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