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次世代モバイルネットワークのための高精度ゼロレーティング

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High-Precision Zero-Rating for Next Generation Mobile Networks

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Abstract Zero-rating is a business strategy where mobile network operators (MNOs) and virtual mobile network operators (MVNOs) will not charge for the traffic of specific applications. Zero-rating has become a killer service for many Mobile Virtual Network Operators (MVNOs) to attract users in the competitive MVNO market. However, how to achieve high-precision zero-rating is still challenging due to two main factors: 1) application providers may update their service (e.g., adding new servers) frequently; 2) upstream ISPs may introduce new in-network functions (e.g., caching and trans-coding) into their networks. Both will change the traffic pattern and signature that MVNOs' application classification is based on. Once the application signature changes, the accuracy of application identification decreases until the MVNOs are aware of the new signature of their targeted application. In this paper, we propose a high-precision zero-rating architecture based on our application-specific slicing technology [1] [2], where we tag traffic with application info at customized smart phone, which can be used to identify applications at MVNOs with 100% accuracy. We examine several zero-rating MVNO networks and observe that the existing zero-rating schemes of MVNOs are not accurate enough, and charge users on those applications that are advertised as count-free, which may result in disruption in the MVNO market. We also posit that the evaluation result highlights the necessity of our proposed architecture.

Key words Zero-rating; Mobile Virtual Network Operator (MVNO); Application Specific Slicing

1. Introduction

Zero-rating, also known as toll-free, sponsored data, refers to mobile communication operators (MNOs), mobile virtual network operators (MVNOs), and Internet service providers (ISP) do not charge their users for the cost of using a particular application or Internet service on their networks, regardless of whether their users are using unlimited or metered data plans.

There have been some Internet services such as Facebook, Wikipedia and Google, which have established several special plans to use zero ratings, as ways of providing broader services to developing markets. These new customers can get some service subsidies from these service providers.

Here are two examples: One is the "Music Freedom" proposed by T-Mobile US, an American mobile service provider, since June 2014, which provides zero-rating access to music streaming media services to its mobile Internet customers. The plan will make it unnecessary for T-Mobile users to pay high fees for access to music content; In addition, such access will not be counted as part of the personal traffic cap, which is what they can achieve before charging for data [4], [5]. Moreover, in November 2015, T-Mobile expand its plan to provide zero-rating access to video streaming services [6].

Another is when Verizon joins AT&T sponsored data work in January 2016. Verizon has announced a new project called FreeBee Data, a newly sponsored data service. This data service enables content providers to pay for wireless providers, and also allows its subscribers to participate in or consume a piece of content without having to count the customer's monthly data allotments [7]. Sponsorship data is somewhat similar to a toll-free call, where a company pays for access costs in order to increase customer engagement.

Zero-rating has many potential benefits: first of all, for users, the most immediate benefit is free access to specific content, which is a very attractive way. Secondly, we can think that it also promotes the frequency of use of mobile devices, as people no longer limit themselves because of a fixed traffic cap, which promotes the consumption of content at the same time. Thirdly, it also promotes the participation of content providers. To the point, the zero-rating service will largely attract a large number of users or customers for an application. So, for some emerging content providers, joining a zero-rating service with a large number of users will undoubtedly bring them higher recognition and popularity.

Also, zero rating can promote competition among Internet service providers: from the perspective of Internet service providers, zero rating service content will become a chip and a tag, which makes Internet service providers distinct from each other and gain significant advantages in competition with independent companies. Zero-rating services are also more important in data-intensive markets such as video streaming. Every new zero-rating service will provide its corresponding service providers with the opportunity to occupy the market. In addition, due to competition among businesses, customers will also benefit from emerging new preferential policies, which is the potential benefit of zero-rating services too.

In general, zero-rating has become a killer service for many Mobile Virtual Network Operators (MVNOs) to attract users in the competitive MVNO market. However, how to achieve high-precision zero-rating is still challenging due to two main factors: 1) application providers may update their service (e.g., adding new servers) frequently; 2) upstream ISPs may introduce new in-network functions (e.g., caching and transcoding) into their networks. Both will change the traffic pattern and signature and the accuracy of application identification decreases.

In this paper, we propose a high-precision zero-rating architecture based on our application-specific slicing technology, where we tag traffic with application info at customized smart phone, which can be used to identify applications at MVNOs with 100% accuracy. We examine several zero-rating MVNO networks and observe that the existing zero-rating schemes of MVNOs are not accurate enough, and charge users on those applications that are advertised as count-free, which may result in disruption in the MVNO market.We also posit that the evaluation result highlights the necessity of our proposed architecture.

The rest of the paper is organized as follows. Section 2 describes the current dilemma and challenges in achieving high-precision zero rating and gives our proposal. Section 3 shows how to conduct high-precision zero-rating analysis. Section 4 shows the further analysis of not zero-rating application. Final summary is in Section 5.

2. Design

This section introduces the current dilemma and challenges in achieving high-precision zero rating. Then we give our proposal: a high-precision zero-rating architecture based on our application-specific slicing technology as depicted in Figure 1, where we tag traffic with application info at customized smart phone, which can be used to identify applications at MVNOs with 100% accuracy using FLARE [8] switch.

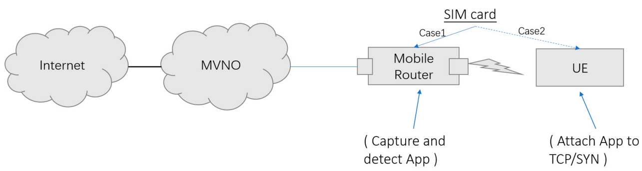

図 1 Network Topology of Application Specific Slicing

2.1 Dilemma

For users, it is very difficult to check whether the zero-rating service they use is true or not, and whether the traffic generated by using the specified application is free. Because firstly, most users don't want to spend too much time and energy to pay attention to their own traffic usage costs, let alone calculate it, unless they were reminded by service providers that they consumed more traffic than the total monthly data capacity due to some special circumstances. Secondly, for most users, most of the time in the day is in the office and at home, and these occasions are usually covered by wireless fidelity. Therefore, users have little chance to consume a large amount of mobile data traffic in a day. Thirdly, the application software users use every day is not limited to those applications and services provided by zero-rating services, which also makes the types of applications constituting users' mobile data consumption sources complex, and it is difficult to measure the number of zero-rating traffic alone.

Appname	Flow_info	Traffic Volume(Uplink)	Traffic Volume(Downlink)	Total
system_server	100.98.222.250_42558_172.217.27.78_80	592	431	1023
com.android.vending	100.98.222.250_38430_172.217.26.46_443	1566	1173	2739
com.google.process.gapps	100.98.222.250_39667_216.58.197.206_443	2549	1833	4382
com.google.android.gms.persistent	100.98.222.250_43953_74.125.204.188_5228	1702	1256	2958
com.google.android.gms.persistent	100.98.222.250_56246_172.217.161.74_443	9493	5387	14880
com.google.android.gms.persistent	100.98.222.250_55710_172.217.161.74_443	2878	1412	4290
com.google.android.googlequicksearchbox:search	100.98.222.250_47682_216.58.221.4_443	2411	4465	6876
com.google.android.youtube	100.98.222.250_36088_216.58.221.170_443	1708	4152	5860
com.google.android.youtube	100.98.222.250_36089_216.58.221.170_443	434	348	782
com.google.android.youtube	100.98.222.250_60103_172.217.25.246_443	1620	4403	6023

図 2 Example of Initial Traffic Statistic of MVNO(A) on 2018/10/03, Including Zero-rating YouTube and Others

For MVNOs, MNOs and ISPs, it is also hard to convince customers that their zero-rating services are with high-precision. They usually only introduce the type of service they provide to customers, but do not explain the principles and mechanisms (although users generally do not take the initiative to question). So, this makes it difficult for providers to come up with a clear and convincing evidence or data to prove that the zero rating service they provide is with high-precision when introducing their zero-rating service to users. Although the real situation is usually that the customer does not care whether they are true or not, but blindly choose to believe. This also implies the risk of being deceived. And a neutral and reputable evaluation organization is desirable.

2.2 Challenges

For most MVNOs (MNOs), application identification is performed using DPI, which is based on a feature database based on the observed traffic history. This means that once the application traffic pattern changes, the accuracy of the zero-rating will decrease until the MVNO becomes aware of the changes and updates their signature database, which can take a considerable amount of time. The main factors that cause changes in the application traffic pattern are: 1) application providers may update their service (e.g., adding new servers) frequently; 2) upstream ISPs may introduce new in-network functions (e.g., caching and trans-coding) into their networks. Both will change the traffic pattern and signature that MVNOs’ application classification is based on, which will decrease the accuracy of application identification until the MVNOs are aware of the new signature of their targeted application.

2.3 Proposal

In this paper, we propose a high-precision zero-rating architecture based on our application-specific slicing technology, where we tag traffic with application info at customized smart phone, which can be used to identify applications at MVNOs with 100% accuracy.

In detail, to realize application-specific slicing, we have designed trailer slicing where meta information on applications and devices at the end of packets. The meta-information may include many other kinds of information, but in this paper, we attach application process name at the end of packets and do the research. And in Figure 1, on the user end, we install our software on smart phones to capture the very first packets for an application (e.g., TCP SYN packets) and examine the process table and the socket table of the operating system to look for a corresponding application process name that uses the flow space and attach the information as a trailer. And with the help of FLARE, which detects app information and creates mapping between flows and apps, MVNO (MNO) can identify application on the tagged trailer with 100% accuracy in real-time.

Under such a mechanism, our network topology is shown in Figure 1. The study is conducted in case 1: SIM card on the pocket WIfI and case 2: SIM card on smart phone (about details are described in sections 3 and 4).

3. High-precision Zero-rating Analysis

In this section, we will show how to conduct high-precision zero-rating analysis under this network architecture, which includes data collection and collation, as well as further analysis.

First of all, we want to briefly introduce what we have done. At present, many MVNOs advertise that they adopt zero-rating strategy for some applications in order to attract a large number of customers. What we have done is to do a certain amount of operation for the so-called zero-rating application under the corresponding network environment provided by MVNO, and collect the flow information generated during this period, then analyze the collected data, then compare the traffic recorded by MVNO, and finally draw the corresponding conclusions. It should be mentioned that in the collected flow information, because of our FLARE work and application-specific slicing, besides the target IP address, port number, and packet length, the flow information also includes the appname of each application, so that we can count the flow information of each application.

In terms of collecting traffic information, we capture all traffic information and save it as a pcap file. Although there is many in-depth package detection software, such as Wireshark, it cannot achieve the expected results for some reasons. Specific details such as: we can get the information of each TCP flow (source IP address, source port number, destination IP address, destination port number, packet length), and the application process name information at the end of the packet. But the problem is that we cannot separate appname and classify each TCP flow information into specific appname and further analyze a large number of data. So, we use the corresponding code script to process the pcap file: match the corresponding appname with the app_index we processed and collect traffic information, and finally get the initial analysis results as shown in Figure 2. The format of flow information is as follows:

Appname | Flow_info (src_ip-src_port-dst_ip-dst_port) | Traffic Volume(Uplink) | Traffic Volume(Downlink) | Total Volume

The meaning of each part is: the name of the application; TCP flow information, including source IP address, source port number, destination address and destination port number; then data volume from source to destination and data volume from destination to source, in units of Bytes, and finally total traffic volume between source and destination.

In the initial results, we successfully obtain the flow information bound to each appname, but since the same appname may have multiple different flow_info, our task is obvious: the different flow information belonging to the same appname is counted and analysis, then get the final result of the traffic consumption of a zero-rating application, which is shown in Figure 3. Here, we select some of the zero-rating applications under MVNO(A), such as YouTube. It's important to note that when we test one of zero-rating apps, we won't launch other zero-rating apps. And our experimental environment is: We put the SIM card of MVNO(A) with zero-rating service on the router end and conduct the test.

First, as can be seen from Figure 3, we successfully count the name of each application process and the traffic it consumes during the test, for example: we get "`com.android.chrome`" consumes 17098 bytes, and zero-rating application "`com.google.android.youtube`" (In the latter part, it is abbreviated as YouTube) consumes 149.08MB of traffic (the result is 2 decimal places, the original result can be more accurate). It should be noted that in order to ensure the accuracy of each test data, we add the traffic consumed by a specific application calculated by the traffic statistics that comes with the mobile terminal: phone (YouTube) in the figure. On the other hand, by adding mobile phone data for comparison, we can see that the traffic consumption of YouTube we calculated is almost the same as that of mobile phone. The difference of result is small

appname	Traffic Volume(Bytes)	Traffic Volume(MB)
init	1607732	
system_server	135437	
unkonwn	2761	
com.andriod.chrome	17098	
com.andriod.vending	202207	
android.process.media	75042	
com.google.android.gms	253302	21.35
com.google.android.gms.persistent	338334	
com.google.android.gms.unstable	83145	
com.google.android.googlequicksearchbox:s	9738	
com.google.android.inputmethod.latin	19553481	
com.google.android.videos	12567	
com.google.process.gapps	93663	
com.google.android.youtube	156323370	149.08
Sum	178707877	170.43
Charged(A-MVNO)		28
phone(youtube)		147

図 3 Example of Traffic Statistic of MVNO (A) on 2018/10/26, Including Zero-rating YouTube and Others

but our statistical results are more accurate, which confirms that we are performing high precision analysis of zero-rating applications.

Then, we can get the test target application `YouTube` consumes 149.08 MB of traffic, if we assign the appname other than "`com.google.android.YouTube`" to other apps, then the other consumes 21.35 MB of traffic. The traffic consumption recorded by MVNO(A) is 28 MB. With reasonable margins, we can confirm that MVNO(A) has charged YouTube for zero rating. This is a successful example of our testing.

In order to ensure the accuracy of the results, we conduct another test on YouTube. For the sake of simplicity, we will show the two results in Figure 4, The results confirm again that YouTube is a zero-rating application.

	Consumed(YouTube)	Consumed(others)	Charged(A-MVNO)
Day-1	122.89MB	22.56 MB	11MB
Day-2	149.08MB	21.35 MB	28MB

図 4 Traffic Statistics of YouTube

The same method, after which we test another three zero-rating applications of MVNO(A), and two of the results are shown in Figure 5.

	Consumed(AbemaTV)	Consumed(Others)	Charged(A-MVNO)
AbemaTV	182.38 MB	39 MB	21MB

	Consumed(AWA)	Consumed(Others)	Charged(A-MVNO)
AWA	281.09 MB	36 MB	42MB

図 5 Traffic Statistics of AbemaTV and AWA

Within the margin of error, it can be concluded from the results that AWA and AbemaTV are zero-rating applications as claimed by MVNO(A). But for another zero-rating application, we get very different results, as detailed in Figure 6.

From the results we can see that the traffic consumed by Q-app in this test is 124.38 MB, and the 127 MB recorded

appname	Traffic Volume(Bytes)	Traffic Volume(MB)
com.android.vending	38209	0.20
com.google.android.gms	19469	
com.google.android.gms.persistent	74359	
com.google.android.youtube	14927	
com.google.process.gapps	7884	
tv.abema	51114	
Q-APP	130425904	124.38
Sum	130631866	124.58
Charged(A-MVNO)		110
phone(Q-app)		127

図 6 Example of Traffic Statistic of MVNO (A) on 2018/10/28, Including Zero-rating Q-app and Others

on the mobile terminal also proves that our statistics are not wrong. In this case, the traffic consumed by the Q-app recorded by MVNO(A) has reached 110 MB. What we can confirm is that Q-app does claim to be a zero rating application as MVNO(A) claims. However, in the range of error tolerance, this numerical result indicates that MVNO(A) does not zero-rate Q-app. Of course, this is only a test result, and the possibility of accidents cannot be ruled out. So, in order to confirm this idea, we conduct a total of 3 tests and show the results as shown in Figure 7. Need to be reminded that we don' t run other applications in the test process and consume a lot of traffic, which can be seen from the statistical 'other data'. That means most of the data traffic in the total traffic data is actually generated by the application under test, which is also to ensure the accuracy of the test.

As can be seen from the results, when the Q-app consumes the 124.38 MB,154.79 MB and 116.63 MB of traffic, the MVNO(A) records the 110 MB, 144 MB and 91 MB. Within these three results, MVNO(A) records the vast majority of the total traffic consumption, indicating that the MVNO(A) does not zero-rate the Q-app.

	Consumed(Q-app)	Consumed(Others)	Charged(A-MVNO)
Day-1	124.38MB	0.2MB	110MB
Day-2	154.70MB	28MB	144MB
Day-3	116.63MB	24MB	91MB

図 7 Three days of Counting Results When SIM Card on the Router End

Then because in the previous series of tests, the mobile phone is tested for specific applications under the MVNO network environment provided by the router. Therefore, in contrast, we directly test the SIM card on the mobile phone side and give the final result which is shown in Figure 8.

This time we get completely different results: when the Q-app consumes the 159.61 MB and 179.24 MB of traffic, the MVNO(A) only records the 5 MB and 3 MB, which shows

	Consumed(Q-app)	Consumed(Others)	Charged(A-MVNO)
Day-1	159.61MB	37MB	5MB
Day-2	179.24MB	3MB	3MB

図 8 Two days of Counting Results When SIM Card on Smart Phone

that MVNO(A) has returned to zero-rated billing for Q-app.

Finally, let us summarize the current tests for MVNO(A). In the research, through our architecture, we test some of the so-called zero-rating applications with high precision. Results shows: MVNO(A) has zero rating billing for YouTube, AWA, and abemaTV within a certain margin of error; but for Q-app, when we put the SIM card on the routing side, Q-app is not zero-rated. And when we put the SIM card directly on the mobile phone, Q-app has become a zero-rating application.

4. Further Analysis of Q-app

In the previous section, we have performed a high-precision test on MVNO(A)'s zero-rating application, and obtain that it' s a zero rating for some of the applications by MVNO(A), but not a zero rating for Q-app applications when SIM card on the router end. This section we conduct a further analysis of why Q-app differs in different situations. And, we will also test another MVNO(B) network to scare Q-app for comparative analysis.

In the further analysis, in order to find out the difference between the SIM card on the routing end and on the mobile phone end, we conduct a more in-depth analysis of the results of each test: that is, the statistics of how much traffic is consumed from each destination IP and each destination port in the Q-app total consumption traffic, and the result is plotted in a table.

In the initial statistics of Q-app, we find that the destination port number is limited to three: 443, 80, and 4070. Based on this, we perform statistical analysis. After in-depth analysis of the data of the SIM card on the routing side and the mobile phone side, we get something in common:

a) When SIM card on the router end:

- The traffic volume of flow with d_ip 193.182.11.65 and d_port 443 is much larger than other flows
- This flow accounts for the vast majority of the total traffic consumption of Q-app

b) When SIM card on the mobile phone:

- The traffic is mainly concentrated on two d_ip: 193.182.11.65 and 104.199.X.X
- The traffic is mainly concentrated on d_port 80 rather than 443

To further simplify the results, we classify the destination IP as 193.182.11.65 and others.

From this we can more clearly see that when the SIM card is on the routing side, MVNO(A) charges the Q-app, and the traffic is mainly concentrated on the destination IP 193.182.XX and destination port 443, and when the SIM card is on the mobile phone, MVNO(A) does not charge for it, traffic is mainly concentrated on port 80. And we can explain as follows: when SIM card on the router end, Q-app provider update its service by adding new cache servers (193.182.11.65). MVNO(A) are not aware of the updates so the traffic to the cache server is still charged. And this case doesn' t happen when SIM card on the phone, which show that the system of zero-rating of MVNO(A) lack of accuracy. Here we give an intuitive histogram of Q-app in figure 9.

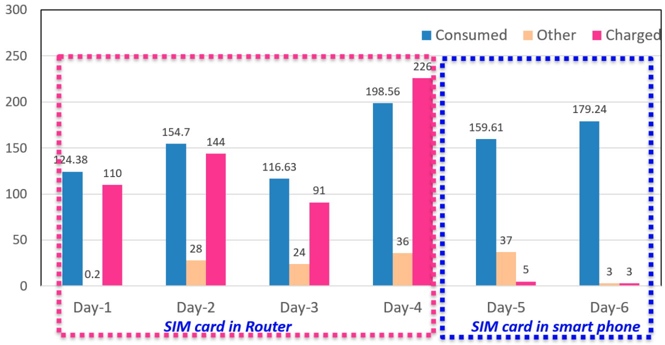

図 9 Comparison of Consumed and Charged Traffic of Zero-rating Q-app of MVNO(A)

In addition, we also test another operator, MVNO(B), which has zero-rating of Q-app,too. The intuitive results are shown in Figure 10. As can be seen from the results, when the SIM card is on the routing side, MVNO(B) still charges the Q-app, which indicates that the system of current MVNOs still lack of accuracy. And when the SIM card is on the smart phone, MVNO(B) charges the Q-app,too. And the charging situation sometimes records most of the traffic generated by Q-app, and sometimes less than 50%, full of uncertainty. Similarly, we also enter the destination IP and destination port for the final result. But there is no obvious difference between the SIM card in the two cases. It is shown from the side that MVNO(B)'s zero rating of Q-app is not accurate.

In conclusion, we have performed high-precision zero-rated tests and comparisons on Q-apps of MVNO(A) and MVNO(B), respectively. The results show that when the SIM card is on the routing side and the mobile phone side respectively, the MVNO(A) performs zero rating and non-zero rating respectively and MVNO(B) is a non-complete zero rating. These all reflect the current lack of accuracy in the MVNO zero rating system.

5. Conclusion and Future Work

In this paper, we propose an architecture based on our

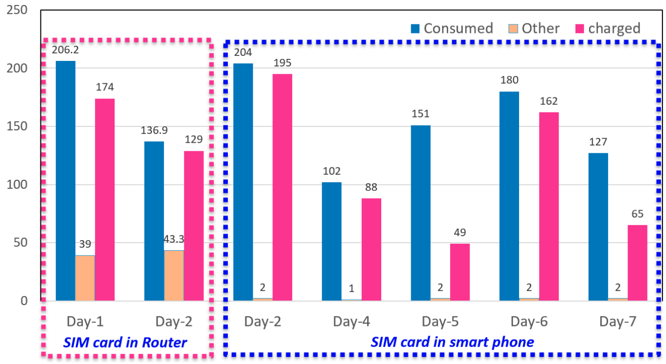

図 10 Comparison of Consumed and Charged Traffic of Zero-rating Q-app of MVNO(A)

application-specific slicing technology, where we tag traffic with application info at customized smart phone, which can be used to identify applications at MVNOs with 100% accuracy. And we examine two zero-rating MVNO networks and observe that the existing zero-rating schemes of MVNOs are not accurate enough, and charge users on those applications that are advertised as count-free, which may result in disruption in the MVNO market. We also posit that the evaluation result highlights the necessity of our proposed architecture.

For the immediate future work, we plan to analyze different MVNO's zero-rating applications and mechanisms for bringing justice in zero-rating marketing.

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