Testimony of Peter Rysavy
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Before the Subcommittee on Communications and Technology
Hearing on "From Core to Edge: Perspective on Internet Prioritization"
April 17, 2018

Chairman Blackburn, Ranking Member Doyle, and other distinguished Members of the Subcommittee, thank you for the opportunity to testify at this important hearing.

Introduction

My name is Peter Rysavy, and I am president of Rysavy Research, an analyst in the wireless industry with more than twenty-five years of experience. I am a leading expert in wireless technology, having worked with many dozens of firms and having published more than 175 reports and articles.

5G will employ sophisticated mechanisms to handle different kinds of traffic flows. This is critical because 5G will address a wider range of use cases than prior technology generations, such as 3G and 4G. Many of the applications envisioned for 5G are of a control nature, which means they need minimal delay and high reliability. These applications will therefore depend on traffic prioritization.

But 5G's reliance on traffic prioritization should not be viewed as problematic for Internet traffic that will not be prioritized. Traffic differentiation and prioritization is not a zero-sum game. Selective application of quality-of-service increases the quality of experience across the subscriber base.

5G needs QoS management, not only for traffic prioritization to support mission-critical applications, but also to enable a fundamental capability in its architecture: network slicing. Network slicing, implemented through virtualization, will allow an operator to provide different services with different performance characteristics to address specific use cases that require low latency and enhanced reliability.

Even with access to new spectrum and expected peak throughputs that will exceed 1 Gbps, 5G networks will be required to manage latency, reliability, massive numbers of connections, and a mix of stationary and mobile users.

The United States has assumed global leadership in 4G and enjoys deep LTE penetration, leading smartphone platforms, and a vibrant application ecosystem. But globally, countries and companies are investing in and concentrating on what will come next with 5G. Constraining 5G with rules that restrict traffic management necessary for the traffic flows anticipated with 5G applications could threaten US leadership in mobile technology and deployment.

Background Details

The millions of mobile applications already transforming the world are just the dawn of the next frontier in mobile broadband—humanity has barely begun exploiting the full potential of wireless technology. The Internet of Things, which will interconnect objects to increase their utility and efficiency, will account for tens of billions of new connections by next decade. IoT's potential is limited only by imagination; use cases include self-driving cars with pre-crash sensing and mitigation, health biometric sensing and response, telemedicine, and proactive monitoring of critical physical infrastructure such as transmission lines.

What many of these new applications have in common are stringent data communication requirements, such as high reliability or minimal delay. This is true even for use cases without particularly onerous bandwidth demands. For example, a self-driving car or autonomous robot may need only a small amount of data, but it might have to receive that data within a few thousandths of a second. In contrast, a user watching a movie is not negatively affected if the video stream leaves the server a second earlier, with no interruption to the viewing experience.

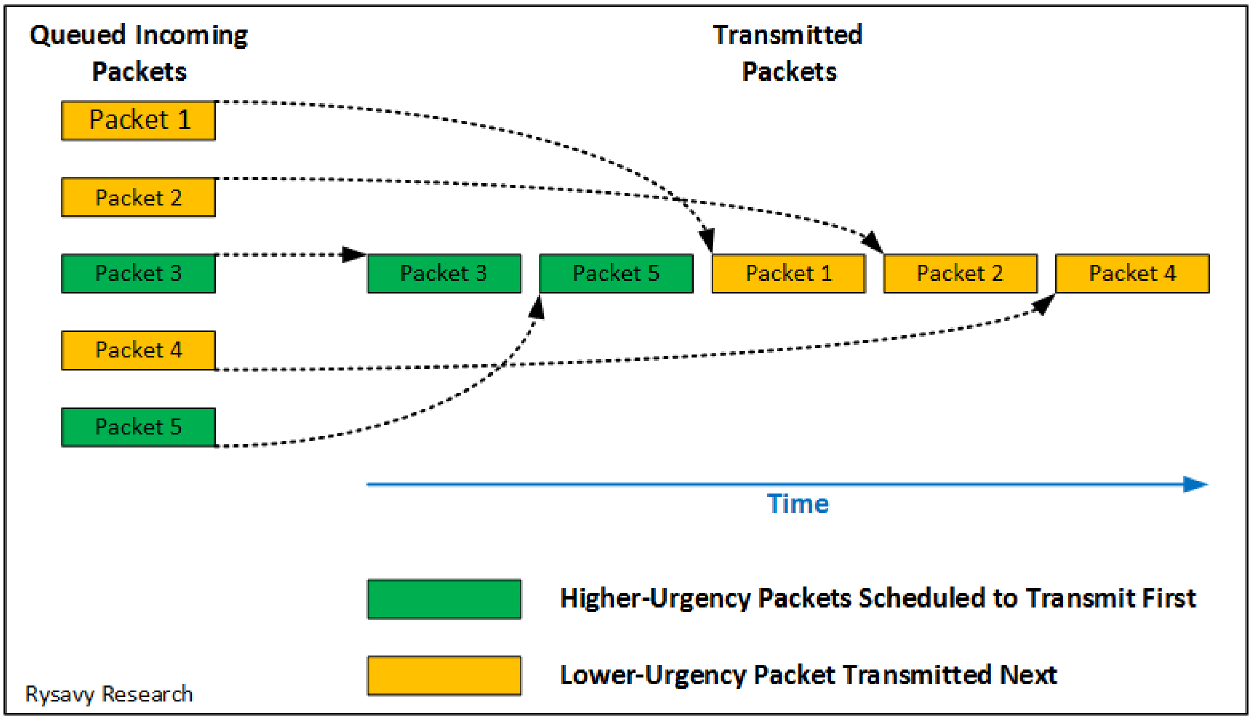
How Quality-of-Service and Prioritization Work

Engineers have designed controls for how packets flow between base stations and users over the radio interface. Traffic-flow parameters include whether bit rates are guaranteed, their priority relative to other traffic flows, the maximum amount of packet delay that can be tolerated by the traffic in question, and the extent of permissible packet loss. LTE specifications define thirteen quality-class identifiers, each with unique parameters.[1] Voice over LTE (VoLTE), which is based on voice-over-IP protocols, uses these QoS mechanisms to provide carrier-grade voice service. Without this control, an LTE voice call would disintegrate if surrounding users were consuming large amounts of data—the network prioritizes voice as higher priority than data. The same prioritization of voice over data also happens in 2G and 3G networks.

Figure 1 shows how, in a QoS-enabled network, the network may schedule higher-urgency packets to transmit first, ahead of those with lower urgency.

[1] For details about LTE QoS, refer to 3GPP TS 23.203. *Technical Specification Group Services and System Aspects; Policy and charging control architecture*, available at http://www.3gpp.org/DynaReport/23203.htm. Specifically, see Table 6.1.7, "Standardized QCI characteristics."

Figure 1: Transmission of Packets According to Their Urgency in a QoS-Enabled Network



5G will employ similar, yet more sophisticated, mechanisms to handle different kinds of traffic flows. This is critical because engineers are designing 5G for a wider range of use cases than prior technology generations, such as 3G and 4G. As described below, 5G will employ a "network slicing" architecture that will depend heavily on QoS management. Many of the applications envisioned for 5G are of a control nature, which means they need minimal delay and high reliability.

Table 1 lists some typical applications and their QoS requirements.

Table 1: Examples of Applications and QoS Requirements

Application	Requirements
Speech	Guaranteed bit rate, low delay, but can tolerate some packet loss.
Internet of Things	Varying requirements depending on use case, but mission-critical applications will require low error rate and low delay.
Streaming (music, video)	High throughput, but can tolerate delay and some packet loss.
Health and medicine	Throughput-rate requirements vary. High priority for critical health applications.
Autonomous vehicles	High throughput and low delay, with low packet loss.
Video conferencing and telepresence	High average throughput, low delay, can tolerate some packet loss on video but less on voice.

Application	Requirements
Operating system or application update	Can run in the background over an extended period, so QoS requirements are minimal.
Web browsing	High average throughput, low error rate, can tolerate slight delay.

Current wireless networks assign equal priority to all third-party application traffic, regardless of the application type. An analogy is a freeway on which fast-moving cars and slow-moving trucks use all lanes equally. The Information Technology & Innovation Foundation (ITIF) states in a report, "To date, we have been able to muddle through with this 'best-effort' system, but many of the exciting innovations around the corner will increasingly require reliable low-latency connections. And while some applications affirmatively need prioritization or some kind of differentiation, other applications can easily tolerate delay or jitter."[2]

The goal of intelligent traffic prioritization is to maximize the quality of experience across the largest number of users and application types possible, allocating higher priority for those applications that need it while not adversely affecting those that do not.

As ITIF states, "Traffic differentiation simply is not a zero-sum game." Because applications have varying quality requirements, selective application of QoS results in higher average quality of experience across the subscriber base. The Broadband Internet Technical Advisory Group agrees, stating, "For example, some differentiation techniques improve the Quality of Service (QoS) or Quality of Experience (QoE) for particular applications or classes of applications without negatively impacting the QoE for other applications or classes of applications."[3]

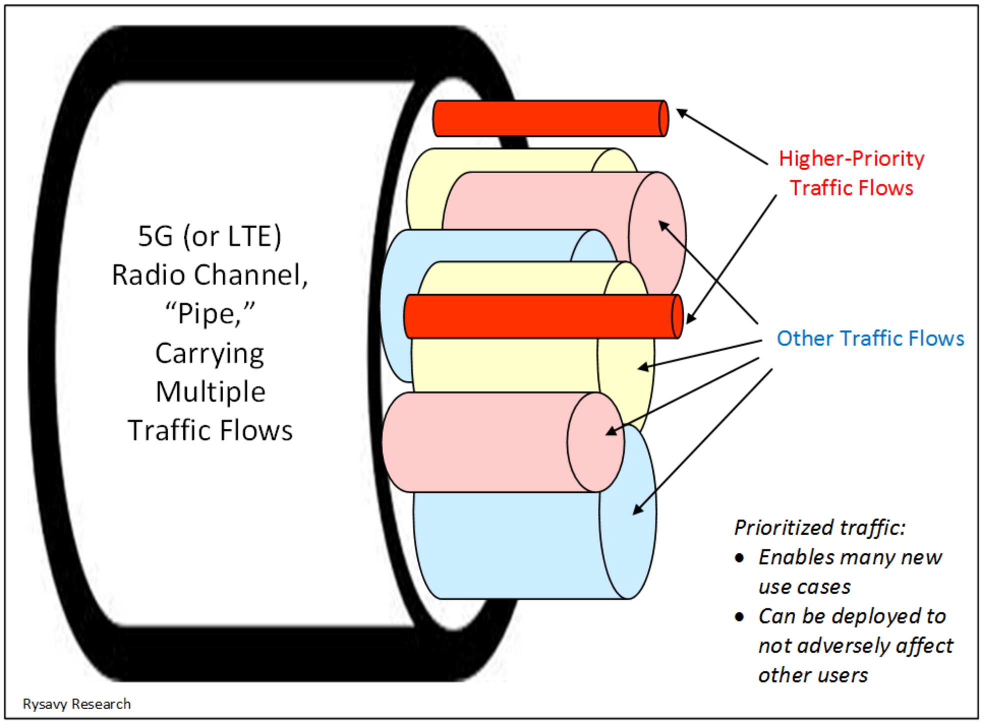
[2] Information Technology & Innovation Foundation, *Crafting a Grand Bargain Alternative to Title II: Net Neutrality with Net Adoption*, October 2015. Available at http://www2.itif.org/2015-alternative-title-ii.pdf.

[3] Broadband Internet Technical Advisory Group, *Differentiated Treatment of Internet Traffic*, October 2015. Available at http://www.bitag.org/documents/BITAG_-_Differentiated_Treatment_of_Internet_Traffic.pdf.

Differentiation is not a zero-sum game. Selective application of QoS increases the quality of experience across the subscriber base.

Figure 2 shows how a 5G wireless network could use QoS management to allocate different priorities to different traffic flows based on their urgency.

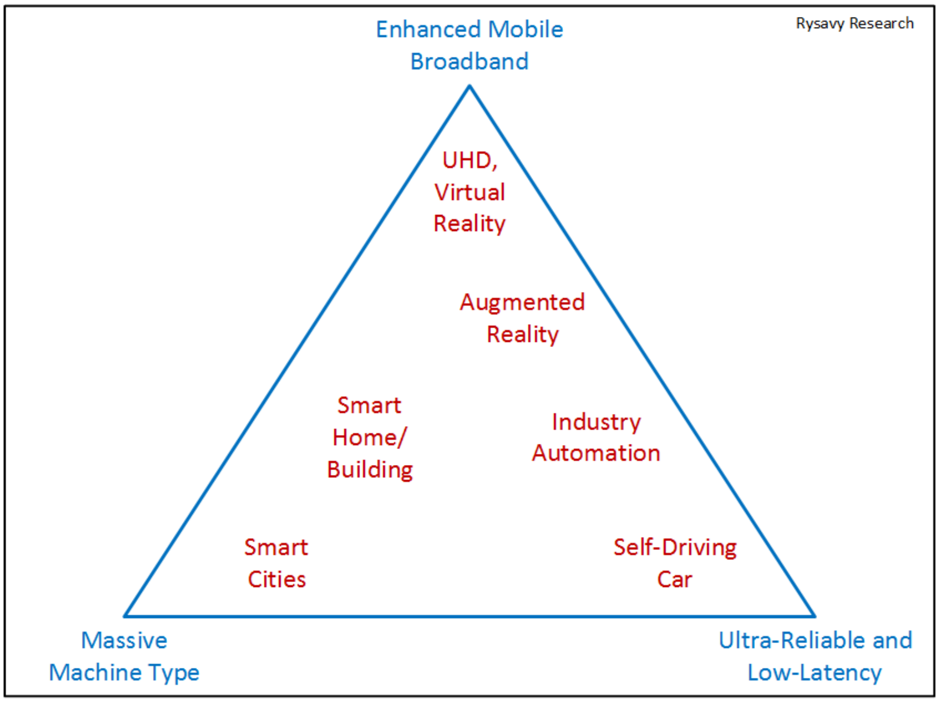
Figure 2: Radio Resource Management in a Wireless Network



5G Use-Case Models Depend on Ability to Provide QoS

The International Telecommunication Union (ITU) is the organization charged with setting 5G objectives and approving final, technical standards for how 5G networks interface with one another and enabled devices. The ITU's recommendation M.2083-0[4] defines use cases using the following model.

Figure 3: ITU 5G Use-Case Model



Enhanced mobile broadband is faster Internet, a turbo-charged version of today's LTE-Advanced networks. "Massive machine type" refers to millions of sensors and controls placed throughout cities, homes, and businesses to improve energy efficiency, transportation, and other logistics. But it is the new ultra-reliable and low-latency category, also referred to as mission critical, that opens cellular networks to capabilities never before possible, such as advanced industry automation and autonomous vehicles. This category of 5G application will depend on the ability to deploy traffic prioritization.

Developers expect response times of less than a millisecond with 5G, ten times lower than with LTE, in which 10 msec latencies are typical. But unprioritized and competing with other traffic, the latency (round-trip time in the network) can be ten times higher, for example, 100 msec. At 60 miles per hour, a car travels nine feet in 100 msec versus only one inch in 1 msec. In a scenario of an intelligent highway warning a car of a pedestrian on the road at a blind curve, that could be the difference between life and death.

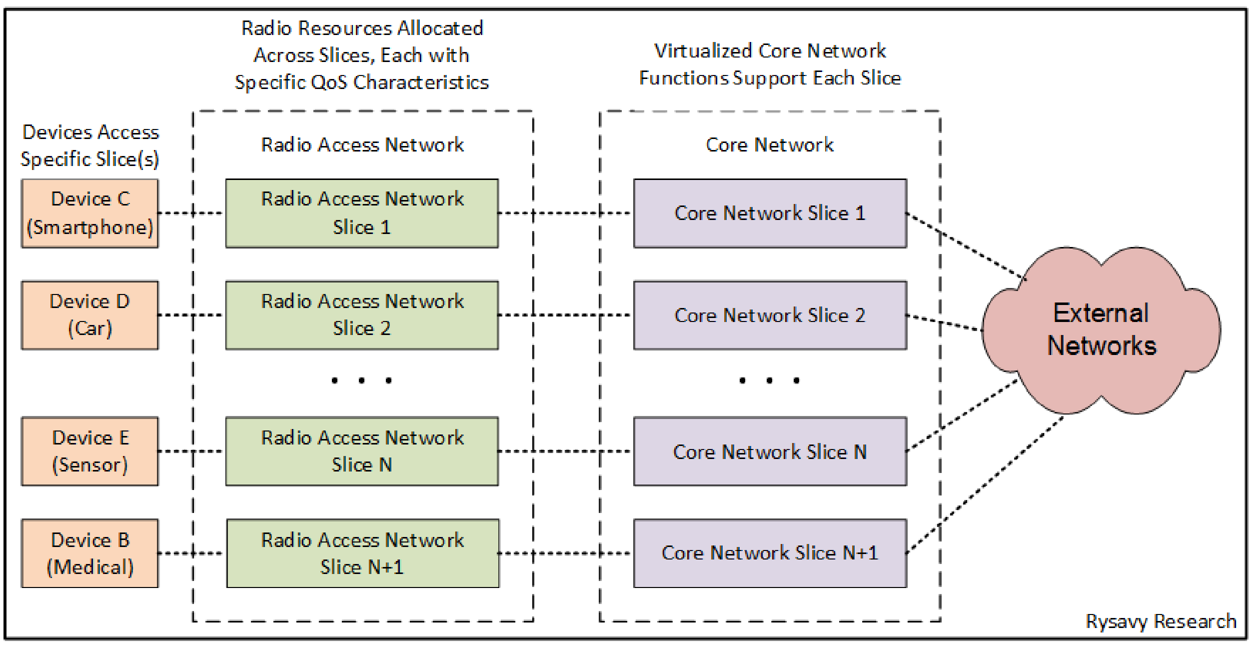
[4] Available at http://www.itu.int/rec/R-REC-M.2083-0-201509-I

5G Networking Slicing and QoS Management

5G needs QoS management, not only for traffic prioritization to support mission-critical applications, but also to enable a fundamental capability in its architecture: network slicing. Network slicing, implemented through virtualization, will allow an operator to provide different services with different performance characteristics to address specific use cases. Each network slice operates as an independent, virtualized version of the network. For an application, the network slice is the only network it sees. The other slices, to which the customer is not subscribed, are invisible and inaccessible. The advantage of this architecture is that the operator can create slices that are fine-tuned for specific use cases. One slice could target autonomous vehicles, another enhanced mobile broadband, another low-throughput IoT sensors, and so on.

Figure 4 shows the network slicing architecture, with devices having access to only the slice(s) for which they have a subscription. Each slice has radio resources allocated, with specific QoS characteristics. Within the core network, virtualized core network functions support each slice and provide connections to external networks.

Figure 4: 5G Network Slicing Architecture



A recent report on network slicing from 5G Americas lists the following examples of slices: serving a utility company, servicing remote control for a factory, serving a virtual operator, and optimizing for streaming video.[5] Operators will be able to provision devices through account configuration so the devices can access specific slices. For consumers, one slice might be for best-effort, unprioritized Web browsing

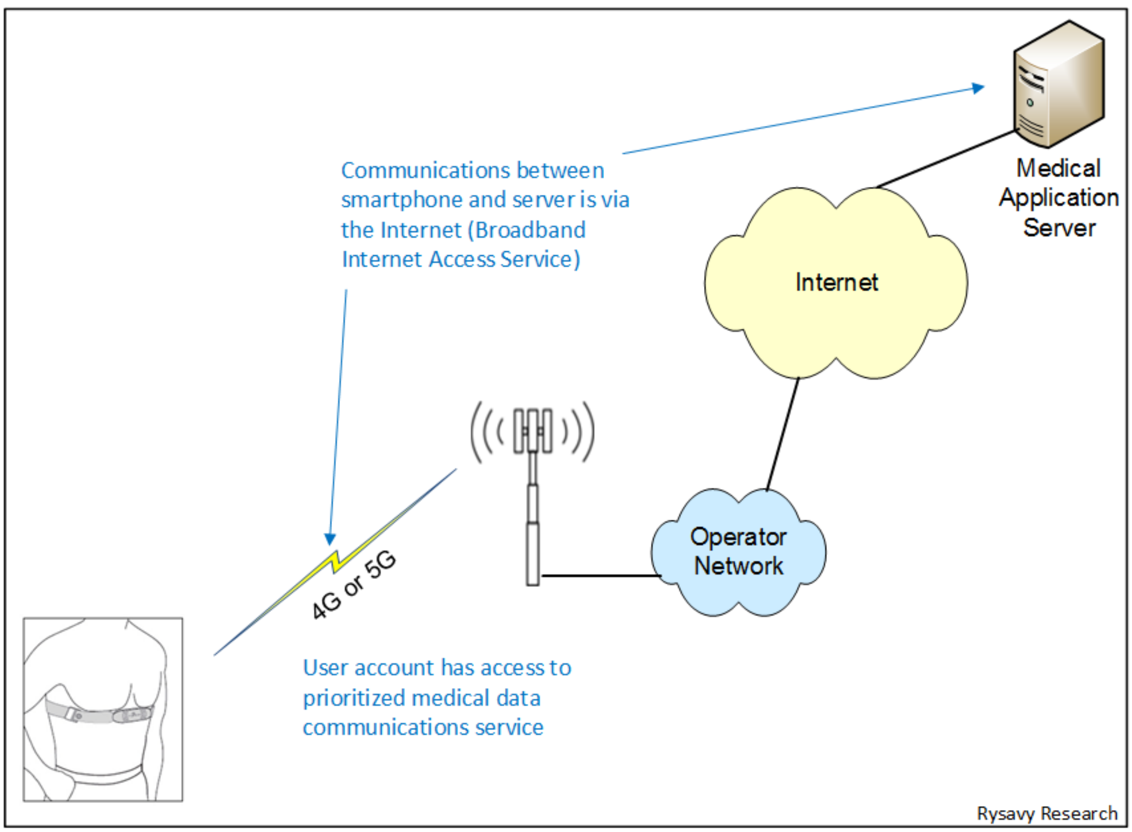
[5] 5G Americas, *Network Slicing for 5G Networks & Services*, November 2016. Available at: http://www.5gamericas.org/files/3214/7975/0104/5G_Americas_Network_Slicing_11.21_Final.pdf.

while another slice could support prioritized telepresence that needs low latency and high bandwidth.

An example of an application using network slicing is a patient wearing body sensors that monitor a heart condition. The sensors continually report vital stats and GPS location to a medical application server, which in turn analyzes the data in real time, taking into account the patient's medications and medical history. Proper analysis depends on receiving accurate data regularly and without interruption—even if the network is congested because a half-dozen people are streaming video while on the same bus as the patient.

To support this application, the operator could provide a network slice customized for medical communications, perhaps one in which throughput rates are modest but the need for reliability and low-latency is high. In other words, the virtualized network that the medical application accesses via the network slice is optimized for the specific needs of health monitoring. In the event of a health event requiring treatment, detected either by the user's monitoring equipment or by the server using more sophisticated data analysis, the system advises the user to see a doctor. If the situation is critical, the monitoring equipment or server could summon an ambulance.

Figure 5: Medical Monitoring Example



Even with access to new spectrum and expected peak throughputs that will exceed 1 Gbps, 5G networks will be required to manage latency, reliability, massive numbers of connections, and a mix of stationary and mobile users. Fundamental to this task will be managing QoS. Different slices will have different QoS requirements, inherently invoking traffic management within each slice. As the 5G Americas paper states, "Each slice is defined to meet different service/application requirements, which are represented in a certain QoS level. A QoS level can be defined by certain performance descriptors such as delay, jitter, packet loss and throughput." In addition, the amount of radio and network resources to apply to each slice, determined based on demand across all slices, will require QoS management.

Conclusion

The communications requirements of today's mobile network applications span a huge range. One application may need high throughput but can tolerate significant delay. Another may need to send only a small number of bits, but these must traverse the network with minimal delay. Future Internet of Things innovations, from intelligent highways to smart-grid monitoring, will only increase the rich variety of application diversity. QoS mechanisms in 4G, and those under development for 5G, provide for application developers and operators to specify needs and for the network to dynamically accommodate them.

Developers and operators have an incentive to enable a diverse range of services, and empowering them to optimize networks to meet competing needs will result in the highest possible quality of experience for the largest number of users. The business case for massive 5G investment can only be made by being able to support all potential applications.

The U.S. wireless industry is at a critical juncture. The United States has assumed global leadership in 4G and enjoys deep LTE penetration, leading smartphone platforms, and a vibrant application ecosystem. But globally, countries and companies are investing in and concentrating on what will come next with 5G. Constraining 5G with rules that unnecessarily undermine its potential would harm the United States' ability to lead the world in 5G technologies and deployment.

Sincerely, Peter Rysavy

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