

5G TECHNOLOGY



What is the Student Venture Fund?

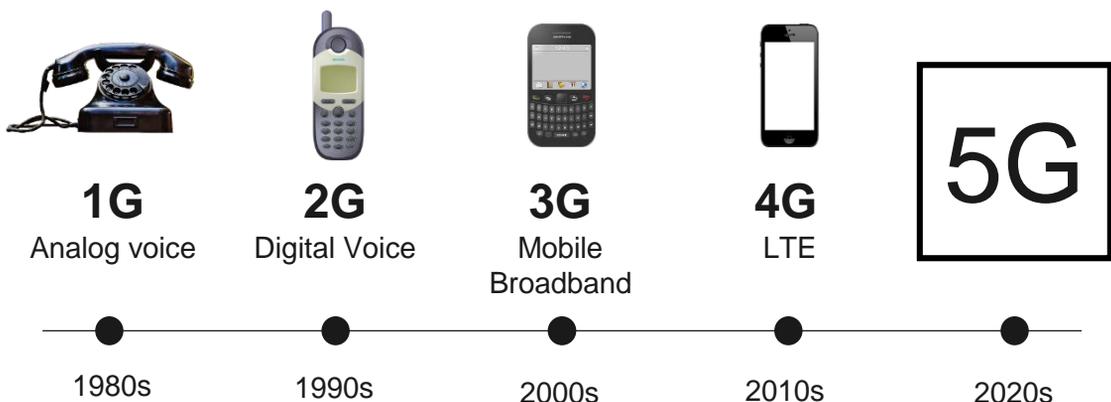
The [Student Venture Fund](#) (“SVF”) at the University of Waterloo provides hands-on training in venture capital investing with guidance from industry experts and supervision by faculty members. Students have the opportunity to make investment recommendations by conducting financial and commercial due diligence on product-market fit, growth potential, and management team.

The SVF Technology Review is a thought leadership initiative allowing SVF members to share our insights on emerging technologies and facilitate cross-faculty discussions on entrepreneurship, technology, and finance. In the first issue in the winter 2019 term, we discussed neurotechnology.

Executive Summary

- 5G is the fifth generation of mobile broadband allowing data to be transmitted at 10-20Gdbp, which is 100x faster than 4G technology
- This expands existing capabilities, such as faster downloads, and creates new applications, such as IoT robotic surgery
- Established enterprises in telecom, device and infrastructure are investing in 5G
- 5G will not displace 4G immediately, as adoption is slowed by several bottlenecks such as infrastructure requirements

History of 5G Technology





History of 5G Technology

	Date	Capabilities
1G	1980s	<ul style="list-style-type: none"> Voice only Maximum speed of 2.4Kbps
2G	1990s	<ul style="list-style-type: none"> Short messaging service (“SMS”) & multimedia messaging service (“MMS”) Call and text encryption Transition from analog to digital Maximum speed of 1Mbps
3G	2000s	<ul style="list-style-type: none"> Mobile broad band Video calling and mobile internet access Maximum speed of 2Mbps
4G	2010s	<ul style="list-style-type: none"> Gaming services, HD mobile TV, video conferencing, 3D TV LTE (long-term evolution) increases channel speed and stability; LTE-A is a more advanced version of LTE Most cell phone models support both 4G and 3G technologies Maximum speed of 1Gbps
5G	2020s	<ul style="list-style-type: none"> Download and upload Ultra HD and 3D video Enables the connectivity of IoT devices allowing remote control of vehicles such as cars and drones Creates new applications like robotics surgery Maximum speed of 10-20Gbps

How Does 5G Work?

Think of cell phones as two-way radios: when you call a friend, your voice is converted into an electrical signal that is transmitted to the nearest cell tower via radio waves, bounced through a network of cell towers, and reaches your friend’s phone. The same thing happens when you send other forms of data, such as photos and video.

Typically, new mobile wireless technologies are assigned a higher radio frequency. For example, 4G occupied frequency bands below 6GHz while 5G occupies the 30-300GHz range. Higher frequencies require greater bandwidth due to shorter wavelengths, allowing more data be sent in less time. However, higher frequency signals cannot travel as far, so multiple input and output antennas are needed to boost signals where 5G is offered.



Shorter wavelength



Longer wavelength



Enhanced Capabilities of 5G Technology



1. Faster speeds

- Downloading an HD movie takes seconds with 5G technology, vs. 10 minutes for 4G LTE



2. Lower latency

- Latency is the response time between a user request and action being taken by a simple function, application, or machine
- Reduced latency decreases lag and improves streaming applications like online gaming, video calling, and interactive live sports
- The manufacturing sector can create products at lower costs, which will be a key factor in applications including autonomous vehicles, smart grid management, and remote healthcare



3. Increased connectivity

- The greater capacity offered by 5G will allow support for more devices and more data-intensive tasks, such as IoT devices in smart cities

Enhanced Mobile Broadband



Ultra-fast Internet



Enhanced Video



Work & Play in the Cloud

Massive Internet of Things



Smart Homes



Smart Buildings



Smart Cities

Ultra-Reliable, Low-Latency Communications



Advanced AR & VR



Connected & Autonomous Vehicles



Mission Critical Broadband



5G Impact

Increasing data traffic

- Increasing adoption of HD music and video streaming and cloud-native applications creates exponential growth in data traffic
- Per Cisco, mobile data usage growth alone is expected to increase from 7 to 49 Exabyte by 2021, representing a 47% CAGR from 2016-21
- 5G can provide the bandwidth needed, which increases the importance of building the infrastructure via small cell network densification

Internet of things

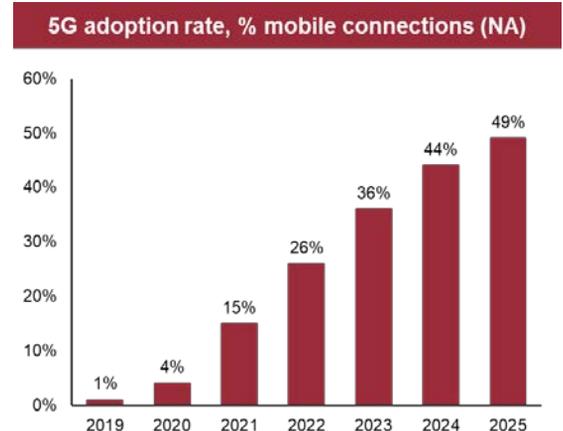
- Currently, all four major US mobile operators are involved with smart city projects ranging from public transit, water management, and street lighting
- Along with smart cities, projects related to smart homes and smart buildings are also being taken on, which will increase the demand for the 5G technology

Robotics surgery

- A doctor can eventually use VR goggles to perform surgery remotely through instant haptic feedback
- Ericsson (Sweden telecommunications company) and King's College in London have showcased this application at the Mobile World Congress in Barcelona

Companies Investing in 5G

Operators, equipment manufacturers, and device manufacturers are all investing in 5G technology to capitalize on mass adoption by consumers.





Equipment Providers in 5G Technology

Nokia

- Has invested 21.2% of total revenues towards R&D in 5G technology
- Vitell and Nokia broadcasted the first end-to-end 5G network in Ho Chi Minh City, Vietnam
- Has confirmed 42 commercial deals for 5G technology across the world
- Federal government has announced \$40 million for Nokia to conduct research on 5G wireless technology in Canada

Ericsson

- Has invested 17% total revenues towards R&D in 5G technology
- Rogers announced a multi-year 5G network plan working with Ericsson to deliver the 5G wireless technology to Canadians subscribers
- Ericsson technology has enabled ENCQOR 5G to roll out Canada's first publicly accessible 5G mmWave service
- Collaborating with NVIDIA to build virtualized 5G radio access networks (RAN)
- Bharti Airtel's (Airtel) Core network will deploy Ericsson's 5G-Ready Cloud Packet Core

Huawei

- Has invested 15% of total revenues towards R&D in 5G technology
- Huawei is further along in the development of 5G than other companies and has plenty of existing infrastructure around the world, in terms of pre-existing 4G networks and in the groundwork for 5G
- This has an impact on 5G rollout because Huawei makes a lot of relatively affordable networking infrastructure needed for 5G

NOKIA





Start-up Companies Leveraging 5G Technology

PERASO

Peraso Technologies

- Location: Toronto (University of Toronto)
- Product/Service: Developed semiconductors for 60 GHz band that allows more data to be pushed through wireless hotspots for applications
- Founder: Sorin Voinigescu
- Year: 2009
- Funding: Raised over \$110.0 million USD



Arralis

- Location: Ireland
- Product/Service: Developed world-leading radio frequency, micro and mmWave technology
- Founders: Barry Lunn, Mike Gleaves
- Year: 2013
- Funding: €52.3 million Euro



Movandi

- Location: California
- Product/Service: BeamXR – allows for ultimate 5G performance through more coverage and lower latency, increased gigabyte hotspots and cost advantages
- Founders: Reza Rofougaran, Maryam Rofougaran
- Year: 2016
- Funding: \$29.7 million USD

Recent Deals

- **July 2019:** Communitel and Rogers have announced a three-year partnership that will see the organizations open a 5G innovation lab in Kitchener-Waterloo
- **September 2019:** Xplornet acquires spectrum to build 5G network for rural Canadians



Canada's 5G Spectrum Auction on April 10th, 2019

- The Canadian treasury received a total of nearly **\$3.5B** from auctioning **104 licences** to Canada's wireless networks
- Rogers invested \$1.7B to enable 5G deployment in urban, suburban and rural communities, which is equivalent to \$1.71 per MHz/POP¹ to acquire 52 of 64 of the 600 MHz spectrum licenses available to the company
- BCE Inc., Canada's largest telecommunications provider, did not win a single licence
- Telus spent \$931.2MM for 12 licences
- Freedom Mobile spent \$492MM for 11 licences in its territories
- Quebecor Inc's Videotron spent \$255.8MM
- The rest of the licences went to smaller companies including Bragg (Eastlink), TBayTel, SaskTel and Xplornet

Other Considerations

Health effects

- Higher data volumes will be transferred over 5G networks using higher frequency fields, which penetrate human tissue, which may cause heatstroke and burns depending on the exposure duration, frequency, and temperature increase
- The WHO IARC classified radiofrequency electromagnetic fields (RF-EMF) as a potential human carcinogen
- However, there has been no conclusive evidence supporting adverse health effects due to long-term exposure to high-frequency fields below the thermal threshold



1. the amount of bandwidth passing one person in the coverage area in a spectrum licence



Sources

- “5G & The Future Of Connectivity: 20 Industries The Tech Could Transform.” *CB Insights Research*, 22 Mar. 2019, www.cbinsights.com/research/5g-technology-disrupting-industries/.
- 5G Adoption Rate Forecast North America 2019-2025*. Statista, www.statista.com/statistics/792427/5g-adoption-rate-forecast-in-the-us/.
- 5G First Look*. IHS Markit, cdn.ihs.com/www/pdf/0519/IHSMarkit_5G_First_Look_Product_Overview.pdf.
- “5G To Account for 15% of Global Mobile Industry by 2025 as 5G Network Launches Accelerate.” *Newsroom*, GSMA, 30 Apr. 2019, www.gsma.com/newsroom/press-release/new-gsma-study-5g-to-account-for-15-of-global-mobile-industry-by-2025/.
- Bashir. *5G Technology Is Coming To Lebanon - What You Need To Know*. TechGeek365, 17 Oct. 2018, techgeek365.com/5g-technology-is-coming-to-lebanon-what-you-need-to-know/.
- “10 Promising European Startups Working on Revolutionary 5G Tech for Super Fast Internet.” *Silicon Canals*, Silicon Canals, 13 June 2019, siliconcanals.com/news/10-promising-european-startups-working-on-revolutionary-5g-tech-for-super-fast-internet/.
- Beaver, Laurie. *North America, APAC Will Drive 5G Adoption*. Business Insider, 14 June 2017, uk.businessinsider.com/north-america-apac-will-drive-5g-adoption-2017-6.
- Beswick, Emma, and Linda Fischer. *What Are the Health Risks Associated with a 5G Network?* Euronews, 26 Mar. 2019, www.euronews.com/2019/03/26/what-are-the-health-risks-associated-with-a-5g-network.
- Blatchford, Andy. “Canada Strikes 5G Wireless Research Deal with Nokia.” *The Globe and Mail*, The Globe and Mail Inc., 24 Jan. 2019, www.theglobeandmail.com/business/technology/article-canada-strikes-5g-research-deal-with-nokia/.
- Brandom, Russell, and Colin Lecher. *Is Huawei a Security Threat? Seven Experts Weigh In*. The Verge, 17 Mar. 2019, www.theverge.com/2019/3/17/18264283/huawei-security-threat-experts-china-spying-5g.
- Campbell, Charlie. *Inside the Controversial Company Helping China Control the Future of the Internet*. Time, 23 May 2019, time.com/5594366/5g-internet-race-huawei/.
- Chandler, Nathan. *How 5G Works*. HowStuffWorks, 29 June 2017, electronics.howstuffworks.com/5g.htm.
- Ciaula, Agostino Di. “Towards 5G Communication Systems: Are There Health Implications?” *International Journal of Hygiene and Environmental Health Volume 221, Issue 3*, Elsevier, 2 Feb. 2018, www.sciencedirect.com/science/article/pii/S1438463917308143.
- Click, BBC. *What Will the Future of 5G Bring? - BBC Click*. Youtube, BBC, 13 Apr. 2018, www.youtube.com/watch?v=5hfZxsGcWB4.
- Collins, Mark, et al. *Are You Ready for 5G?* McKinsey & Company, www.mckinsey.com/industries/telecommunications/our-insights/are-you-ready-for-5g.
- Davies, Jamie. “Ericsson and Nokia up Their R&D Game to Compound Huawei Misery.” *Telecoms.com*, Informa PLC. Informa Telecoms & Media Limited, 28 Aug. 2019, telecoms.com/499382/ericsson-and-nokia-up-their-rd-game-to-compound-huawei-misery/.
- Davies, Jamie. “FCC Unveils Plans for US 5G Spectrum Auctions.” *Telecoms.com*, Telecoms.com, 3 Aug. 2018, telecoms.com/491301/fcc-unveils-plans-for-us-5g-spectrum-auctions/.
- “Ericsson and NVIDIA Partner on Virtualized 5G RAN.” Ericsson, Telefonaktiebolaget LM Ericsson, 22 Oct. 2019, www.ericsson.com/en/press-releases/2019/10/ericsson-and-nvidia-collaborate-to-accelerate-virtualized-5g-radio-access-networks-with-gpus.
- Ericsson – Remote Healthcare with King's College. Ericsson, 4 July 2019, www.ericsson.com/en/cases/2017/kings-college/kings-healthcare.
- Grijpink, Ferry, et al. *The Road to 5G: The Inevitable Growth of Infrastructure Cost*. McKinsey & Company, www.mckinsey.com/industries/telecommunications/our-insights/the-road-to-5g-the-inevitable-growth-of-infrastructure-cost.



Sources

- Iacopino, Pablo, et al. *The 5G Era in the US*. GSMA, www.gsmaintelligence.com/research/?file=4cbbdb475f24b3c5f5a93a2796a4aa28&download.
- “IARC CLASSIFIES RADIOFREQUENCY ELECTROMAGNETIC FIELDS AS POSSIBLY CARCINOGENIC TO HUMANS.” *International Agency for Research on Cancer*, World Health Organization, 31 May 2011, www.iarc.fr/wp-content/uploads/2018/07/pr208_E.pdf.
- International, CNBC. *What Is 5G? | CNBC Explains*. YouTube, 29 Mar. 2018, www.youtube.com/watch?v=2DG3pMcNNlw&t=24s.
- “KDDI Selects Ericsson for 5G RAN.” *Ericsson*, Telefonaktiebolaget LM Ericsson, 30 Sept. 2019, www.ericsson.com/en/press-releases/2019/9/ericsson-and-kddi-to-deploy-5g-network.
- McCann, John, and Mike Moore. *5G: Everything You Need to Know*. TechRadar, 29 July 2019, www.techradar.com/news/what-is-5g-everything-you-need-to-know.
- Molla, Rani. *The Fuss over 5G, Explained*. Vox, 30 May 2019, www.vox.com/recode/2019/5/30/18642877/5g-huawei-china-rural-mobile-broadband-ookla-politics.
- “Movandi.” *Crunchbase*, Crunchbase Inc. , www.crunchbase.com/organization/movandi#section-overview.
- Ontario Centres of Excellence Inc. “ENCQOR 5G Launches First Public MmWave Service in Canada.” *Cision*, CNW Group Ltd, 23 Oct. 2019, www.newswire.ca/news-releases/encqor-5g-launches-first-public-mmwave-service-in-canada-836582620.html.
- Paddon, David. “Wireless Spectrum Auction Sees Telcos Shell out \$3.5B for New Blocks of Airwaves | CBC News.” *CBCnews*, CBC/Radio Canada, 11 Apr. 2019, www.cbc.ca/news/business/wireless-spectrum-auction-1.5093475. RogersMike. “Rogers Secures New 5G Spectrum in Every Province and Territory.” *About Rogers*, 10 Apr. 2019, about.rogers.com/2019/04/10/rogers-secures-new-5g-spectrum-every-province-territory/.
- “Startup Based on U of T Researchers' Work Raises US\$42 Million to Alleviate Congested Wireless Networks.” *University of Toronto News*, University of Toronto, 20 Feb. 2019, www.utoronto.ca/news/startup-based-u-t-researchers-work-raises-us42-million-alleviate-congested-wireless-networks.
- The Canadian Press. “Rogers to Open Lab in Waterloo Region to Develop Commercial Uses for 5G Networks.” *CityNews Toronto*, Rogers Digital Media Television, 17 July 2019, toronto.citynews.ca/2019/07/17/rogers-to-open-lab-in-waterloo-region-to-develop-commercial-uses-for-5g-networks/.
- The Promise and Potential of 5G*. IHS Markit, *The Promise and Potential of 5G*, cdn.ihs.com/www/pdf/0419/IHS-Markit-Technology-5G-The-Promise-Potential.pdf.
- The Race For 5G: How 20 Corporations Are Building The Future Of Connectivity*. CB Insights Research, 23 Apr. 2019, www.cbinsights.com/research/corporations-5g-future-connectivity/.
- “What Is 5G? Understanding The Next-Gen Wireless System Set To Enable Our Connected Future.” *CB Insights Research*, 20 June 2019, www.cbinsights.com/research/5g-next-gen-wireless-system/.
- “Xplornet Acquires Spectrum in 600 MHz Auction.” *Xplornet*, Xplornet Communications Inc. , 11 Apr. 2019, www.xplornet.com/about/news/xplornet-acquires-spectrum-in-600-mhz-auction/.
- Yu, Ben. *The Convergence of 5G and AI: A Venture Capitalist's View*. VentureBeat, 30 Mar. 2019, venturebeat.com/2019/03/31/the-convergence-of-5g-and-ai-a-venture-capitalists-view/.

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