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6G AND BEYOND

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The 'flip-flop' qubit

UNSW Sydney research demonstrates a new type of quantum bit in silicon, called 'flip-flop' qubit, which can facilitate the construction of a large-scale quantum computer.

Dr Tim Botzem, Professor Andrea Morello and Dr Rostyslav Savytskyy in the quantum computing lab at UNSW Sydney. Photo: Richard Freeman/UNSW

A team led by Professor Andrea Morello has just demonstrated the operation of a new type of quantum bit, called 'flip-flop' qubit, which combines the exquisite quantum properties of single atoms, with easy controllability using electric signals, just as those used in ordinary computer chips.

A deliberate target: electrical control of a single-atom quantum bit
"Sometimes new qubits, or new modes of operations, are discovered by lucky accident. But this one was completely by design," says Prof. Morello. "Our group has had excellent qubits for a decade, but we wanted something that could be controlled electrically, for maximum ease of operation. So we had to invent something completely new."

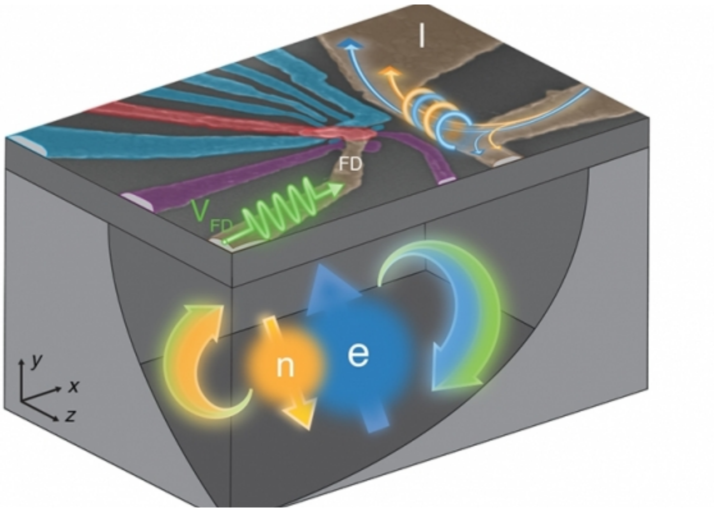
Prof. Morello's group was the first in the world to demonstrate that using the spin of an electron as well as the nuclear spin of a single phosphorus atom in silicon could be used as 'qubits' – units of information that are used to make quantum computing calculations. He explains that while both qubits perform exceptionally well on their own, they require oscillating magnetic fields for their operation.

"Magnetic fields are difficult to localize at the nanometer scale, which is the typical size of the individual quantum computer components. This is why the very first proposal for a silicon quantum bit envisaged having all the qubits immersed in a uniform oscillating magnetic field, applied across the whole chip, and then using local electric fields to select which qubit gets operated."

A few years ago, Prof. Morello's team had a realization: by defining the qubit as the combined up-down / down-up orientation of the electron and the nucleus of the atom would permit controlling such qubit using the electric fields alone. Today's result is the experimental demonstration of that visionary idea.

"This new qubit is called 'flip-flop' because it's made out of two spins belonging to the same atom – the electron and the nuclear spin – with the condition that they always point in opposite directions," says Dr Rostyslav Savytskyy, one of the lead experimental authors of the paper, published in Science Advances.

"For example, if the '0' state is 'electron-down / nucleus -up' and the '1' state is 'electron-up / nucleus-down', changing from '0' to '1' means that the electron 'flips' up and the nucleus 'flops' down. Hence the name!"



Sketch of the silicon nanoelectronic device that hosts the 'flip-flop' qubit. The nuclear spin ("n", in orange) and the electron spin ("e", in blue) flip-flop with respect to each other while always pointing in opposite directions

The theory predicted that by displacing the electron with respect to the nucleus, one could program arbitrary quantum states of the flip-flop qubit.

"Our experiment confirms that prediction with perfect accuracy," says Dr Tim Botzem, another lead experimental author.

"Most importantly, such electron displacement is obtained simply by applying a voltage to a small metallic electrode, instead of irradiating the chip with an oscillating magnetic field. It's a method that much more closely resembles the type of electrical signal normally routed within conventional silicon computer chips, as we use every day in our computers and smartphones."

A promising strategy to scale up to large quantum processors

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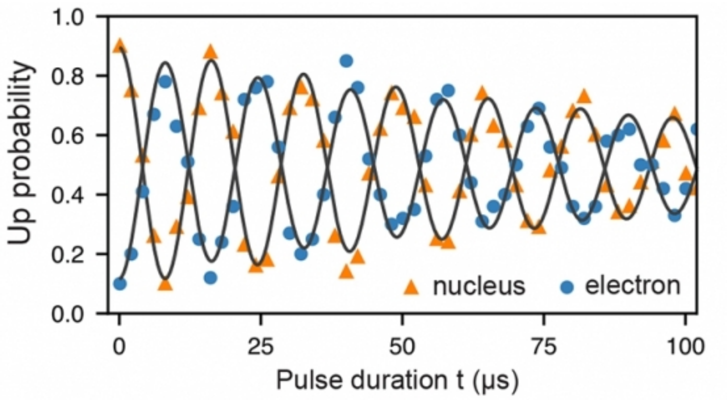


"The standard way to couple spin qubits in silicon is by placing the electrons so close to each other that they effectively 'touch'," says Prof. Morello.

"This requires the qubits to be placed on a grid of a few 10s of nanometres in pitch. The engineering challenges in doing so are quite severe. In contrast, electric dipoles don't need to 'touch' each other – they influence each other from the distance. Our theory indicates that 200 nanometres is the optimal distance for fast and high-fidelity quantum operations.

"This could be a game-changing development, because 200 nanometres is far enough to allow inserting various control and readout devices in between the qubits, making the processor easier to wire up and operate."

SOURCE: UNSW

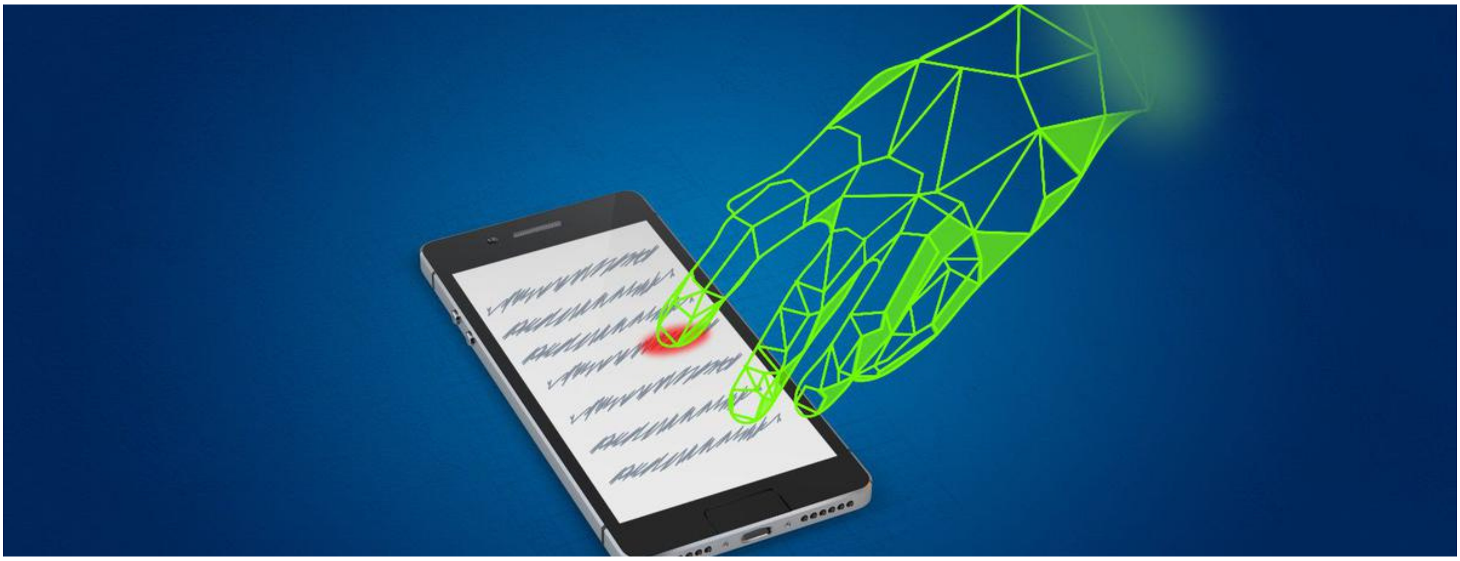
Combating hate speech online with Artificial Intelligence

Hate speech on social media is increasing, deterring some people from participating while creating a toxic environment for those who remain online. Many different AI models have been developed to detect hate speech in social media posts, but it has remained challenging to develop ones that are computationally efficient and are able to account for the context of the post—that is, determine whether the post truly contains hate speech or not.

A group of researchers in the United Kingdom has developed a new AI model, called BiCapsHate, that overcomes both of these challenges. They describe it in a study published 19 January in IEEE Transactions on Computational Social Systems.

Tarique Anwar is a lecturer in the department of computer science at the University of York, who was involved in the study. He notes that arguments online can often lead to negative, hateful, and abusive comments, and that the existing content-moderation practices of social media platforms fail to control this.

"MISUNDERSTANDING ARISING FROM IGNORANCE BREEDS FEAR, AND FEAR REMAINS THE GREATEST ENEMY OF PEACE."



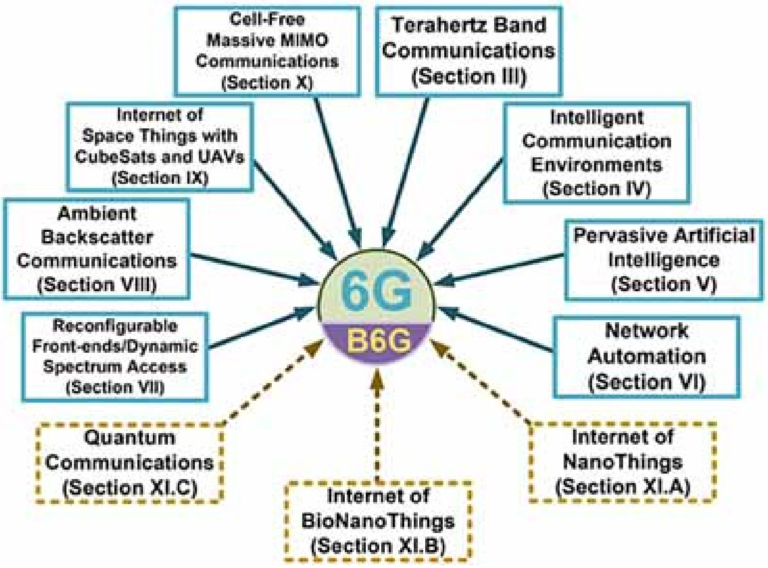
Hate speech is defined by the Cambridge Dictionary as "public speech that expresses hate or encourages violence towards a person or group based on something such as race, religion, sex, or sexual orientation".[1] Hate speech is "usually thought to include communications of animosity or disparagement of an individual or a group on account of a group characteristic such as race, colour, national origin, sex, disability, religion, or sexual orientation".[2] Legal definitions of hate speech vary from country to country.

There has been much debate over freedom of speech, hate speech, and hate speech legislation.[3] The laws of some countries describe hate speech as speech, gestures, conduct, writing, or displays that incite violence or prejudicial actions against a group or individuals on the basis of their membership in the group, or that disparage or intimidate a group or individuals on the basis of their membership in the group. The law may identify protected groups based on certain characteristics.[4][5][6] In some countries, hate speech is not a legal term.[7] Additionally, in some countries, including the United States, much of what falls under the category of "hate speech" is constitutionally protected.[8][9] In other countries, a victim of hate speech may seek redress under civil law, criminal law, or both.

“No one is born hating another person because of the color of his skin, or his background, or his religion.”

6G AND BEYOND

6G and beyond will fulfill the requirements of a fully connected world and provide ubiquitous wireless connectivity for all. Transformative solutions are expected to drive the surge for accommodating a rapidly growing number of intelligent devices and services. Major technological breakthroughs to achieve connectivity goals within 6G include: (i) a network operating at the THz band with much wider spectrum resources, (ii) intelligent communication environments that enable a wireless propagation environment with active signal transmission and reception, (iii) pervasive artificial intelligence, (iv) large-scale network automation, (v) an all-spectrum reconfigurable front-end for dynamic spectrum access, (vi) ambient backscatter communications for energy savings, (vii) the Internet of Space Things enabled by CubeSats and UAVs. In recent years, the rise of artificial intelligence (AI) has infiltrated various areas, and AI will usher in unprecedented paradigm shifts in 6G by providing native intelligence. Considering AI from the initial phase of developing concepts and technologies for 6G will give us more opportunities to take advantage of AI for improvement of overall network operation in terms of performance, cost, and the ability to provide various services.
However, the potential technologies and practical implementation of 6G networks are still in the very early stages, and many challenges have yet to be identified and resolved. This Special Issue aims to introduce and highlight the latest developments and emerging research in 6G and beyond wireless communication systems.



The main contribution of this article is a bold, forward-looking vision of 6G systems (see Fig. 1) that identifies the applications, trends, performance metrics, and disruptive technologies, that will drive the 6G revolution. The proposed vision will then delineate new 6G services and provide a concrete research road map and recommendations to facilitate the leap from current 5G systems towards 6G.

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6G FUTURE

As the name suggests, 6G is the successor to 5G communications technologies. Beyond supporting mobile, 6G will support technology like automated cars and smart-home networks, helping create seamless connectivity between the internet and everyday life.

Currently, 5G promises download speeds many times faster than 4G LTE networks and with significantly less latency. Naturally, we can expect 6G networks to use higher frequencies than 5G networks and provide substantially higher capacity and much lower latency. Current projections call for 6G to hit a maximum speed of one terabit per second (Tbps), which is 100-times faster than 5G. In terms of frequency, 6G looks to elevate from 5G's frequency of 60 kilobits and reach 95 kilobits. 6G will use more advanced radio equipment and a greater volume and diversity of airwaves than 5G, including an extremely high frequency (EHF) spectrum that delivers ultra-high speeds and huge capacity over short distances. All 6G networks will have integrated mobile edge computing technology, not an add-on like current 5G, providing benefits such as improved access to AI capabilities and support for sophisticated mobile devices and systems.

The 6G network must be more efficient than 5G and consume less power. Energy efficiency achieved through digitization is critical for a more sustainable mobile industry because of the anticipated growth in data generation. The 6G network can power the applications needed to make this happen.

The network must be more than just secure. It must also be reliable. While privacy is an important component of security, consistent, reliable, and rapid, end-to-end data delivery, such as that needed to support the safe and efficient operation of driver-less vehicles without concerns about potentially dangerous latency glitches, is essential.

The COVID-19 pandemic helped clarify the importance that future networks will need to emphasize societal and economic needs by focusing on expanded global access instead of just performance. Many areas worldwide, particularly rural and underprivileged areas, are without broadband access. Future networks will need to serve an ever-increasing number of users and their anticipated network use cost-effectively to achieve the goal of universal wireless communications access. 6G satellite technology, combined with intelligent surfaces capable of reflecting electromagnetic signals, can deliver low latency and multi-gigabit connectivity. This potential could be especially trans-formative in parts of the world where providing access to conventional mobile networks is too difficult, too expensive, or both. The advances provided by the open radio access network (Open RAN) should also help drive down network costs.

6G BENIFITS

6G will be significantly more energy-efficient, turning off components and scaling down capacity when the demand is lower. Energy efficiency will be a major design criterion in 6G along with the other metrics such as capacity, peak data rate, latency, and reliability.