

# **GROWING THE MARKET FOR CONSUMER AND ENTERPRISE ROBOTICS**

---

Key topics we will discuss in this paper include:

- › Exploring the possibilities of personal assistant robots
- › Role of robotics in developing household and educational robots
- › Role of Drones in the robotics story
- › Impact of AI and cloud technologies on the robotics market
- › Role of broadband networks

# INTRODUCTION

**The first time the word robot was used was in a 1920s story to describe a humanoid machine<sup>1</sup>, but the biggest success for robotics up to the present day has not been humanoid assistants but industrial robot arms in factories. Now, however, non-industrial robots are becoming important as artificial intelligence improves, and fast networks enable the use of cheaper, more powerful data analysis, information retrieval and control delivered from the cloud.**

Non-industrial robots – also referred to as service robots<sup>2</sup> – do not have to be fully autonomous; they can assist a human user or be remotely operated. They include the following broad types:

- Military vehicles – land- and water-based as well as aerial drones
- Specialist medical robots, including for robot-assisted surgery, and powered exoskeletons
- Autonomous vehicles for both commercial and consumer applications, including self-driving cars, logistics and surveying on land, in water and in the air, and consumer and enterprise aerial drones
- Personal assistant robots, including those for care and companionship applications, customer service applications and information provision
- Household and commercial cleaning robots of many kinds
- Research, educational and toy robots.

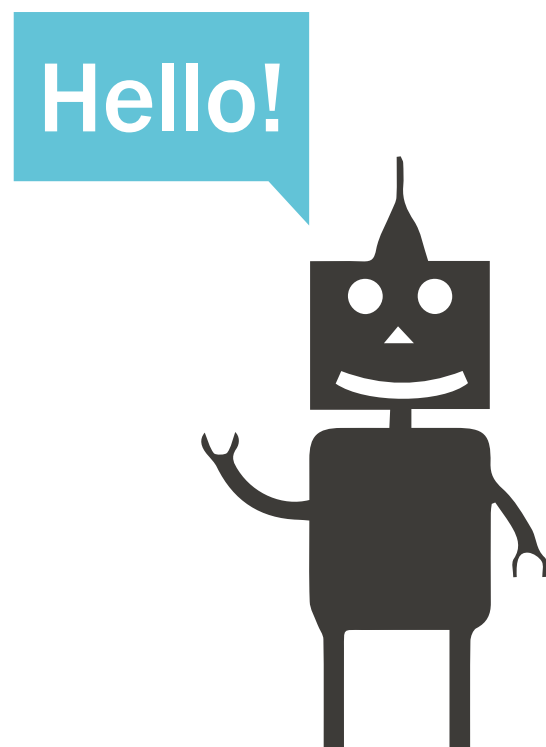
Both professional and domestic applications for service robots exist; often professional service robots are supervised or controlled by a trained operator. Some robots could be classified in more than one type: for instance, automated wheelchairs may be considered both a logistics robot or a personal care robot.

A special class of robots – generally used as personal assistants – are humanoid robots, that typically act as an interface between a person and the digital and physical worlds. These types of robot may increasingly become governing robots, managing other specialised robots performing different tasks.

Many categories of service robots are expected to sell in large numbers in the future: professor Atsuo Takanishi of Waseda University in Japan – one of the world's foremost experts on robotics – believes that regulation is the only thing holding back the consumer robot market. The International Federation of Robotics (IFR) projects<sup>3</sup> sales of domestic service robots to grow to around 42 million in total over the three years 2016-2019, and estimate that the total number of professional service robots sold in 2015 was 25% up on the previous year, at 41,000.

Some in the industry have a longer-term view that robot numbers will grow to become huge: Masayoshi Son, CEO of SoftBank, said in 2015<sup>4</sup> that he believes that by 2040 the number of robots will exceed the human population.

Military and specialist medical robots are expensive so their usage is restricted to relatively few organisations. Self-driving cars represent a very large opportunity that is dealt with in other white papers in this series. Many logistics robots operate in industrial settings and are closely associated with factory or warehouse automation. This paper looks more closely at personal assistant robots, household and research / educational / toy robots, and also domestic and commercial aerial drones. It highlights some recent innovations, and the role of mobile communications networks, the cloud and AI in enabling the arrival of the robotic age.



1- <http://www.sciencefriday.com/segments/science-diction-the-origin-of-the-word-robot/>

2- <http://www.ifr.org/service-robots/>

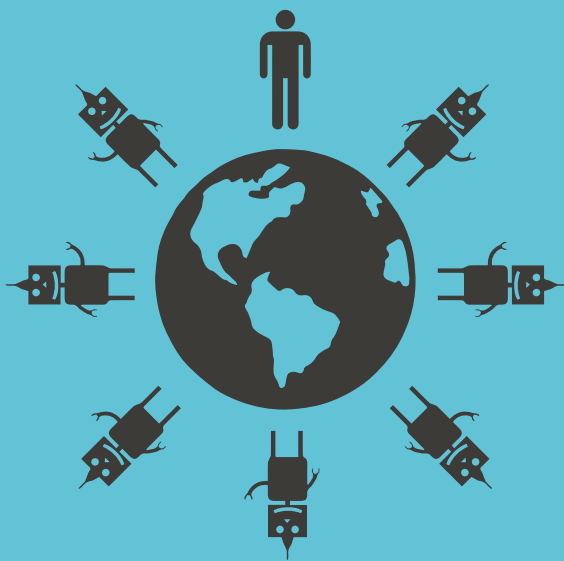
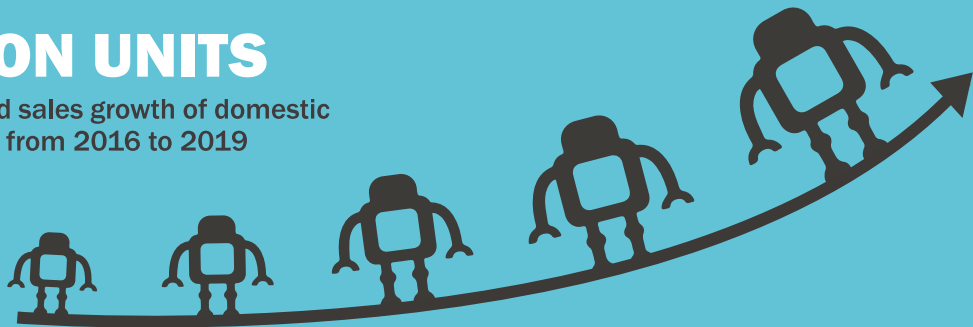
3- [http://www.ifr.org/fileadmin/user\\_upload/downloads/World\\_Robotics/2016/Executive\\_Summary\\_Service\\_Robots\\_2016.pdf](http://www.ifr.org/fileadmin/user_upload/downloads/World_Robotics/2016/Executive_Summary_Service_Robots_2016.pdf)

4- <https://www.techinasia.com/softbank-ceo-intelligent-robots-need-emotions-compassion>

# KEY DATA

## 42 MILLION UNITS

is the expected sales growth of domestic service robots from 2016 to 2019



## 2040

by then the robot population will have exceeded the human population worldwide

## 500 MILLION DOLLARS

the market value of commercial drones by the end of 2016



---

# PERSONAL ASSISTANT ROBOTS

---

**Many companies have developed personal assistant robots over the last 10 years or so. Leading companies producing humanoid personal assistants include Hitachi, Fujitsu and Softbank Robotics, and one could also consider room-based microphone / speaker devices such as Google Home and Amazon Echo to be part of this type of robotic system: an interface to the digital and connected world.**

Some humanoid personal assistant robots have sold in quite large numbers. For instance, Pepper, produced by SoftBank Robotics, had sold 10,000 units by mid-2016, for commercial use in at least 700 businesses such as shops, hotels and museums, as well as for domestic use. Producers aim to get the price down, increase ease of use, and make personal assistant robots more socially acceptable – and that is why these robots are often humanoid.

One of the most important markets for such robots in the near future is expected to be for care of the elderly. Softbank Robotics, for instance, has been active in research projects<sup>5</sup> involving medical staff and care homes to study the social acceptability of robots, and found that robots can become accepted. Multiple business models might be developed for this application, involving private and public health insurance providers, families and elderly people themselves buying or leasing robots, outright or on a subscription. The price of the robot must be balanced by the value of the services that the robot brings. Softbank believes that care of the elderly is a market where there is a business case to be made, even if at the moment robots cannot prepare meals or carry out complex manipulation of objects.

**“When we started to develop humanoid robots, we had in mind to make them for everyone. Today, their abilities with hands and brain are still quite limited and we explain that they are just for entertainment and companionship. But what they can do fits very well with the needs of elderly people: they can remind people to take medicine, and help with cognitive regeneration and physical coaching, or even getting something from another room. Care for the elderly is the first market where this type of robot could be really useful.”**

**- Rodolphe Gelin**, EVP and Chief Scientific Officer, Softbank Robotics

Other markets for personal assistant robots are customer service and information points in shops and museums, where robots can be used as the first point of contact with the customer or visitor, and as hotel concierges<sup>6</sup>.

---

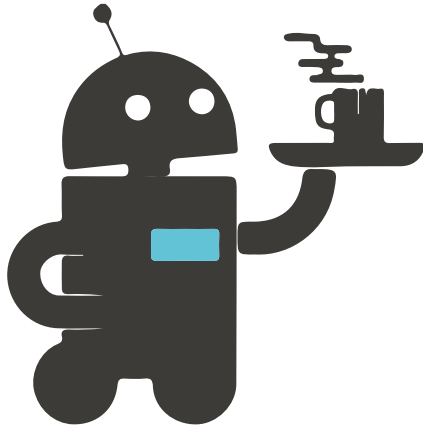
5 - <http://projetromeo.com/en>

6 - <https://www.ibm.com/blogs/watson/2016/03/watson-connie/#prclt-74IGE1df>

---

# HOUSEHOLD, EDUCATIONAL AND TOY ROBOTS WILL DEVELOP THEIR CAPABILITIES

---



Some forms of household robots are now mainstream: robotic vacuum cleaners, pool cleaners and other devices are sold as autonomous devices in growing numbers, and their manufacturers have grown to be large companies. For instance, the US company iRobot, which manufactures household cleaning robots, had a turnover in 2014 of US\$557million, and has offices worldwide.

Some forms of household robots are now mainstream: robotic vacuum cleaners, pool cleaners and other devices are sold as autonomous devices in growing numbers, and their manufacturers have grown to be large companies. For instance, the US company iRobot, which manufactures household cleaning robots, had a turnover in 2014 of US\$557million, and has offices worldwide.

**“I think there will be a humanoid robot in the centre of everything, acting as an interface to possibly multiple other specialist robots. Remember that it is much harder to have a humanoid robot using a conventional vacuum cleaner than it is to have one controlling a dedicated robotic vacuum cleaner; the humanoid robot is primarily for interaction.”**

**- Rodolphe Gelin**, Softbank Robotics

One emerging domestic application is security and monitoring (such as checking the house while the owner is away, perhaps using drones), and there is already a business case to be made for commercial inspection robots in large buildings or sites: a presentation by China Mobile at the 2016 Global Mobile Broadband Forum held in Japan analysed the maintenance inspection of a large data centre of 10,000 sq m that takes three engineers to inspect daily. The analysis showed that one cloud-enabled inspection robot could perform this inspection at one tenth of the cost, if suitable technology was in place (30Mbit/s data rate to stream video, 99% network availability, ~10ms latency, multiple connection options, and a control system).

Other household and educational applications include teaching children foreign languages (with a humanoid robot acting like a foreign visitor in the home), entertainment and game-playing (including in the adult entertainment sector), and to be the ultimate link to the digital world.

---

# DRONES ARE SET TO PLAY AN IMPORTANT PART IN THE ROBOTICS STORY

---



In the last few years drones – specifically, small unmanned aerial vehicles (UAVs) – have become much more stable, capable, affordable and easily controllable, via smartphone apps as well as dedicated consoles. They are increasingly common in consumer and commercial use, though there are still issues of regulation of drones to resolve in many countries before they can really take off commercially. There are fears they may interfere with other air traffic in some locations, and there are some concerns over privacy and safety. In addition, battery-powered drones still have restricted flight time. Despite this, analyst company Juniper Research forecast an 80% rise in sales of commercial drones in 2016<sup>7</sup> and a market value of \$500 million; research firm NPD estimates that total drone sales tripled in 12 months to April 2016<sup>8</sup>.

The potential for drones to become a platform for multiple applications – and a significant part of the Internet of Things – is undeniable. Among interesting uses of drones are parcel delivery (including for medicines in otherwise inaccessible environments) and communications network nodes. EE in the UK<sup>9</sup> is testing drones as a possible base station technology for remote areas.

Cameras are the devices most likely to be attached to a drone, and the potential for video recording is not limited to consumer use. Aerial surveying for inspection and maintenance is an early successful use case for commercial drones. With the right connectivity, video images can be streamed directly from the drone camera to remote locations for expert assessment, and such capabilities are a significant help in surveying difficult-to-access locations at much lower cost than using a helicopter or conventional aircraft. Huawei has worked with China Mobile Guangxi (CMG) to use drones carrying radio-frequency survey equipment around base station sites<sup>10</sup> and the results were extremely positive.

**“UAV RF base station surveys represent a new survey method that provides an excellent solution to the problems of visiting sites that are hard to access. They greatly increase the efficiency of maintenance and optimization work ... we will expand the use of UAVs to work such as network optimization testing and transmission line patrols, which will help further boost automation. I think UAVs will prove very useful in these and a number of other areas.”**

**- Huang Tao**, VP, China Mobile Guangxi

---

7 - <https://www.juniperresearch.com/press/press-releases/commercial-drone-sales-to-rise-by-more-than-80>  
8 - <https://www.npd.com/wps/portal/npd/us/news/press-releases/2016/year-over-year-drone-revenue-soars-according-to-npd/>  
9 - <http://www.mobileeurope.co.uk/press-wire/ee-and-nokia-use-drones-to-set-up-rural-4g-network-in-scotland>  
10 - <https://www.huawei.com/es-CL/publications/winwin-magazine/25/efficiency-with-drone-site-surveys>

---

# AI AND CLOUD TECHNOLOGIES CAN CATALYSE THE MARKET

## Part 1

---

**The more intelligent robots become, the more tasks they can perform and the less supervision they require from humans. Artificial intelligence (AI) has evolved to the point where it can defeat human opponents at complex logic puzzles such as the games of chess<sup>11</sup> and go, processing hundreds of millions of moves per second – far in excess of the power of a human brain.**

**“Current AI technologies are not yet mature, but we have made use of them in our robotics work. Examples are artificial neural nets, genetic algorithms, reinforcement learning and A\* search algorithms”**

**- Prof. Atsuo Takanishi**, Product Director, Dept of Modern Mechanical Engineering, Waseda University, Japan

The virtual assistants in current smartphones (Apple Siri, Microsoft Cortana, Google Now and others) demonstrate how AI has become mainstream, and such assistants can respond in natural language to spoken questions within milliseconds. One field of AI – machine learning – will help service robots to become better at what they do, both by learning from the interactions with the user, and by learning from the collected experiences of other connected robots.

Some aspects of AI – such as learning how to do some repetitive tasks better, can be delivered on autonomous, un-connected robots, but the greatest benefits occur when there is access to huge computing power in the cloud, and through access to shared data. The reduction in cost of high-performance computing and storage in the cloud has the potential to dramatically improve the intelligence of robots, assuming the widespread availability of appropriate connectivity. Robotics companies agree that robots need to be autonomous and connected. The reason for this is that it is important that robots can function safely should a network connection fail; but at the same time, they are aware of the huge potential of the cloud.

For instance, rapid access to the knowledge resources of the Web can help with providing contextual understanding so personal assistant robots can become proactive and propose services and applications. Information in the cloud is always up to date, and it enables “collective intelligence” and better learning. It is accessible from any devices, and it is easy to deploy new services. Data can also be backed up. It will be important to address issues of data privacy and security

but these issues are broader than just the robot market, and are being addressed by many organisations looking at how the Internet of Things can be secured.

There have been attempts over many years to develop robotics cloud platforms with open interfaces, or based on proposed sets of industry standards. These include:

- IEEE DaVinci project<sup>12</sup>
- The open source Robot Operating System (www.ROS.org) and related projects<sup>13</sup>
- Berkeley University object recognition and grasping project<sup>14</sup>
- RoboEarth<sup>15</sup>
- Rapyuta<sup>16</sup>
- Robobrain<sup>17</sup>

Robot manufacturers have learned from these pioneering projects and are designing new cloud robot systems and platforms with new robotic applications in mind, including those where robots work with humans. For instance, at the 2016 Global Mobile Broadband Forum, Cloud Minds (www.cloudminds.com) proposed a robotics system consisting of:

- an operational platform with AI to complement human intelligence (a human can take over control of the remote robot devices at any time, and machine learning is complemented with human learning)
- a secure mobile cloud computing network infrastructure
- a universal mobile device to connect and control all cloud robots.

---

11 - <https://www.research.ibm.com/deepblue/meet/html/d.3.3a.shtml>

12 - <http://ieeexplore.ieee.org/document/5509469/>

13 - [http://wiki.ros.org/rosbridge\\_suite](http://wiki.ros.org/rosbridge_suite)

14 - <http://queue.ieor.berkeley.edu/~goldberg/pubs/Grasping-with-Google-Goggles-icra-2013.pdf>

15 - <http://roboearth.ethz.ch/>

16 - <http://rapyuta.org/>

17 - <http://robobrain.me>

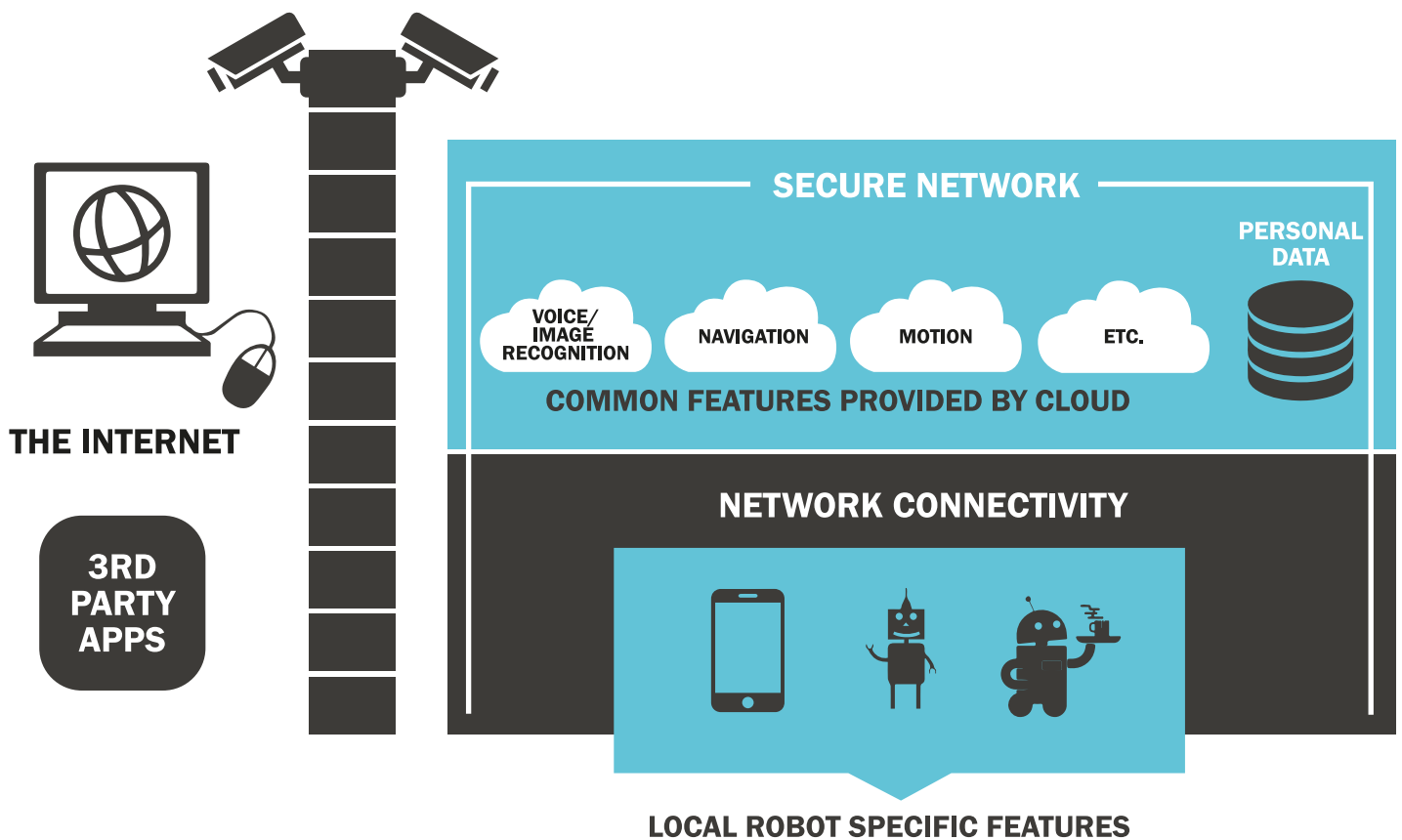
# AI AND CLOUD TECHNOLOGIES CAN CATALYSE THE MARKET

## Part 2

“The best ecosystem for a robotic society is ‘cloud-network-terminal’ ... end-to-end security and high performance is mandatory for robotics so the network must be secured, and the AI cloud services must be hardened against attack. At the device end, there must be authentication and data isolation”

- Jiang Haitao, VP, Product Management, CloudMinds

THE DIAGRAM BELOW ILLUSTRATES HOW A CLOUD ROBOT PLATFORM IS BUILT





# THE ROLE OF MOBILE BROADBAND NETWORKS

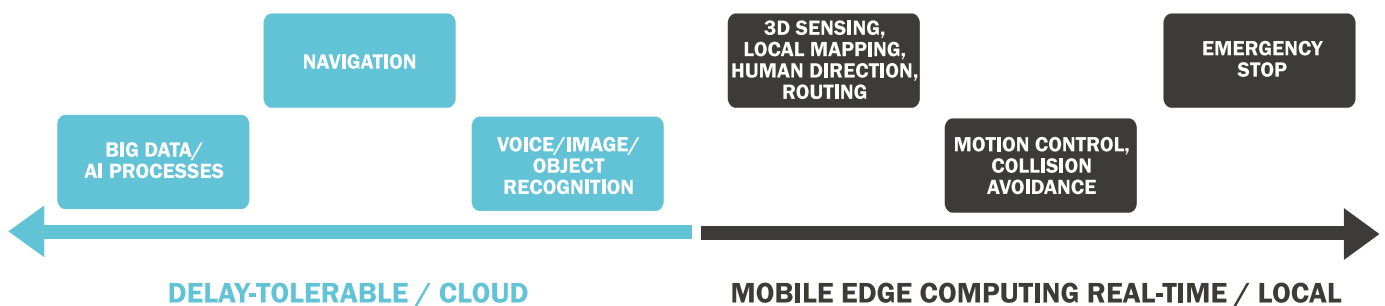
**It is clear from the way that robots will develop to use cloud-based resources that connectivity will become increasingly important – in fact, the development of robotics and wireless networks will be complementary. Currently, most robot connectivity is through local area wireless networks such as WiFi, and the use of robots is mostly confined in buildings though Qualcomm and AT&T are testing aerial drones using 4G cellular networks for control<sup>18</sup> and China Mobile has demonstrated early 5G network drone control<sup>19</sup>.**

Current robots do not need breakthroughs in cellular network technology. As cellular networks move from 4G to 5G, not only will robots be able to move freely outside, but the abilities of robots will increase because of advances in a number of areas:

- **Latency:** A mobile robot can have only a small delay between a “stop” instruction and the robot complying. At 30km/h, a 100ms delay (typical in 3G networks) would result in the robot moving 83cm; 4.5G and 5G networks will reduce latency by at least an order of magnitude.
- **Bandwidth:** Robots equipped with sensors and cameras and microphones may stream very large amounts of data, and may have a requirement for around 40Mbit/s even using compression.
- **Reliability:** Robots will need excellent coverage indoors and at cell edges to give the required reliability.
- **Battery consumption:** mobile robots will need to be battery powered, so communications should be as small a drain on battery reserves as possible.
- **Scalability:** If consumer robot numbers grow significantly as the industry is expecting, networks must be able to cope with connecting them all.

While advanced mobile networks will be able to meet robot requirements, it is likely that some functions will remain on-board; and some will be duplicated in the cloud. Mobile edge computing (where servers are placed close to the point of use) can reduced latency and the load on networks.

**The illustration below shows the likely distribution of robot functions between on-board, mobile edge and cloud resources. As networks develop, more of these processes will move to the left of the diagram.**



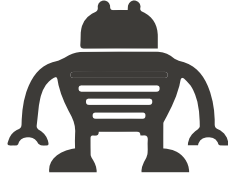
It is clear that as robots develop to take advantage of cloud resources and the capabilities of advanced mobile networks, many different types of organisation will need to cooperate.

**“We see a cloud robot ecosystem developing involving wireless operators and their network equipment vendors, chipsets and modules makers, robot manufacturers, integrators, and cloud platforms.”**

- **Yang Guang**, China Mobile research Institute

# KEY TAKEAWAYS

---



---

**01** Non-industrial (service) robots are becoming more important and markets for both professional and domestic robots are growing fast



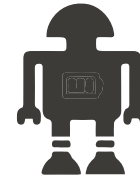
---

**02** There is the opportunity for personal assistant robots – including humanoid robots – to control other devices and to act as a single intelligent point of contact with the physical and digital worlds.



---

**03** Care of the elderly is a promising early market for service robots: their capabilities are well-matched to meeting the needs of elderly people in their homes, initially by providing companionship and assistance with cognitive and some physical tasks.



---

**03** Cloud-based robotics is the key to increasing the capabilities of service robots: using the power of AI and machine learning delivered from low-cost cloud computing resources, and sharing learned experiences, robots can become more useful. Social acceptability will be increased as robots are seen to know their users better with each interaction and to contextualise their responses.



---

**05** Use of the cloud requires high-performance communications (and some robot functions will remain on-board): 5G is very well placed to meet the performance requirements by delivering low latency, high bandwidth, high reliability, low power and scalability.



---

Copyright © 2016 Huawei Technologies Co., Ltd. All rights reserved. No part of this document may be reproduced or transmitted in any form or by any means without prior written consent of Huawei Technologies Co., Ltd. Trademarks and Permissions Huawei and other Huawei trademarks are the property of Huawei Technologies Co., Ltd. All other trademarks and trade names mentioned in this document are the property of their respective holders.

**NOTICE**

The product, service, or feature that you purchase should be restricted by the Huawei commercial contract and the clauses in the contract. All or a part of products, services, or features described in this document may not be purchased or used. Every effort has been made in the preparation of this document to ensure the accuracy of the contents, but the statements, information, and recommendations in this document do not constitute a warranty of any kind, expressed or implied. The information in this document is subject to change without notice. Every effort has been made in the preparation of this document to ensure the accuracy of the contents, but the statements, information, and recommendations in this document do not constitute a warranty of any kind, expressed or implied.