

WIRELESSLY CONTROLLING UNMANNED AIRCRAFT AND ACCESSING ASSOCIATED SURVEILLANCE DATA

TECHNICAL FIELD

[0001] The present invention is directed generally to systems and methods for wirelessly controlling unmanned aircraft and accessing associated surveillance data.

BACKGROUND

[0002] Unmanned aircraft or aerial vehicles (UAVs) provide enhanced and economical access to areas where manned flight operations are unacceptably costly and/or dangerous. For example, unmanned aircraft outfitted with remotely controlled cameras can perform a wide variety of surveillance missions, including spotting schools of fish for the fisheries industry, monitoring weather conditions, providing border patrols for national governments, and providing military surveillance before, during, and/or after military operations.

[0003] Existing techniques for controlling unmanned aircraft systems suffer from a variety of drawbacks. For example, existing unmanned aircraft systems (which can include the aircraft itself along with control devices, launch devices, recovery devices, and storage methods) are typically controlled using either direct RF communication or satellite communication. Direct RF-based control is limited by its short range and high power requirements. It also requires specialized equipment at both the UAV and the ground control station.

[0004] While controlling UAVs by satellite may allow for longer-range communications when compared with direct RF-based control, satellite control is typically limited by low bandwidth and low data rate limits. An example of a satellite-based control technique used in the past is Iridium. Iridium is a low-orbit satellite communications system that provides a long-range data connection at a rate of ~2.4k bits per second. Not only does control by satellite have the drawback of limited bandwidth and low data rate, it also, like direct RF, typically involves high power requirements, high cost, and specialized equipment (e.g., relay stations and large dishes for transmit/receive).

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 is a system diagram showing an example of an environment in which a wireless telecommunication network is used along with mobile wireless devices and possibly other supporting technologies to communicate command and control data to one or more UAVs and/or to access and monitor signals and data transmitted from the UAVs in an embodiment of the invention.

[0006] Figure 2 is a block diagram showing an example of a mobile wireless device, such as the mobile wireless device of Figure 1, that can be used as a ground control station for controlling a UAV via the wireless telecommunication network in an embodiment of the invention.

[0007] Figure 3 is a block diagram showing an example of control components of a UAV, such as the UAV of Figure 1, which can be used for communication via the wireless telecommunication network in an embodiment of the invention.

[0008] Figure 4 is a block diagram showing an example of a computer, such as the supporting technology/computer of Figure 1, which may also be used for communication via the wireless telecommunication network in an embodiment of the invention.

[0009] Figure 5 is a flow chart showing an example of a routine performed at a mobile device used for controlling a UAV via the wireless telecommunication network in an embodiment of the invention.

[0010] Figure 6 is a flow chart showing an example of a routine performed by a collection of one or more components onboard a UAV, which enable the UAV to communicate via the wireless telecommunication network in an embodiment of the invention.

[0011] Figure 7 is a flow chart showing an example of a routine performed by a computer that is capable of establishing a wireless communication link (via a wireless telecommunication network) to control one or more UAVs or, alternatively, is wirelessly connected to a mobile wireless communication device that is, in turn, used to communicate with one or more UAVs via the wireless telecommunication network in an embodiment of the invention.

[0012] Figure 8 is a flow chart showing an example of a routine performed onboard an aircraft that is capable of forming a network bridge that enables communication of control devices with other aircraft, such as UAVs that are otherwise outside the wireless telecommunication network in an embodiment of the invention.

DETAILED DESCRIPTION

I. Overview

[0013] Aspects of the invention are directed generally to systems and methods for wirelessly controlling unmanned aircraft and accessing associated surveillance and monitoring data. In one embodiment a wireless communication network (e.g., an existing cell phone network) is used along with handheld devices (cell phones or PDAs), and possibly other supporting technologies, to communicate command and control data to one or more UAVs and/or to monitor signals and data transmitted from UAVs. For example, this may include controlling the take off and/or landing of one or more UAVs, controlling the aerial maneuvers of one or more UAVs controlling the weapons systems of one or more UAVs, receiving mission surveillance information from one or more UAVs (including border surveillance information, tracking of moving or stationary subjects, etc.), receiving UAV health and/or status monitoring information, monitoring other aircraft in the area of one or more UAVs, etc. In this way, long-range communications can be achieved without having to design and build custom direct communications systems and without having to rely on expensive and complex satellite systems.

[0014] In some embodiments, the use of the wireless communication network and supporting devices provides nearly unlimited communication range capabilities within urban areas, where direct RF communication is typically inhibited by obstructions such as buildings and other large structures. Moreover, urban areas typically have dense pre-existing wireless communication capabilities due to the high demand for mobile phone service and related services in these areas.

[0015] While the supporting devices used to control the UAVs via the wireless communication network may be custom devices, pre-existing devices may also be used. For example, many off-the shelf wireless devices are highly programmable

(e.g., due, in part, to programming languages like Java), support arbitrary user interfaces, and connect via wireless link to other devices including wireless devices (e.g., on the ground or in the air) and computer systems. Moreover, such wireless devices are typically small, portable, inexpensive, and have low power requirements.

[0016] In addition, because wireless network bandwidth is typically an order of magnitude larger than satellite bandwidth, the use of a wireless telecommunication network and supporting devices to control UAVs can allow for higher bandwidth, which translates directly into more responsive control and improved video quality and frame rates (e.g., for sending video back from a UAV). For example, current-generation wireless systems can run at ~300k bits per second – compared with ~2.4k bits per second for existing satellite systems.

II. System Architecture

[0017] Figures 1-4 and the following discussion provide a brief, general description of a suitable environment in which aspects of the invention can be implemented. Aspects of the invention may be stored or distributed on computer-readable media, including magnetically or optically readable computer disks, as microcode on semiconductor memory, nanotechnology memory, organic or optical memory, or other portable data storage media. Indeed, computer-implemented instructions, data structures, screen displays, and other data in accordance with aspects of the invention may be distributed over the Internet or over other networks (including wireless networks) on a propagated signal via a propagation medium (e.g., an electromagnetic wave(s), a sound wave, etc.) over a period of time, or on any analog or digital network (packet switched, circuit switched, or other scheme).

[0018] Aspects of the invention can be embodied in a special purpose computer or data processor that is specifically programmed, configured, or constructed to perform one or more of the computer-executable instructions explained in detail herein. Aspects of the invention can also be practiced in distributed computing environments where tasks or modules are performed by remote processing devices that are linked through a communication network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[0019] Figure 1 is a system diagram showing an example of an environment in which a wireless telecommunication network 102 (e.g., an existing cellular network) is used along with mobile wireless devices 104 (e.g., cell phones and/or PDAs) and possibly other supporting technologies 106 (e.g., personal computers (PCs)), to communicate command and control data to one or more aircraft/UAVs 108 and/or to access and monitor signals and data transmitted from the UAVs 108. The UAVs 108, handheld wireless devices 104, and other supporting technologies 106 combine with the wireless telecommunication network 102 to form a type of mesh network 110.

[0020] Example implementations of the wireless telecommunication network 102 include UMTS (universal mobile telecommunication system), GSM (global system for mobile communications), GPRS (general packet radio service), EDGE (enhanced data rates for GSM evolution), CDMA (code division multiple access), IS-136/TDMA (time division multiple access), EV-DO (evolution-data optimized), analog, 3GSM (third generation global system for mobile communications), iDEN (integrated digital enhanced network), etc.

[0021] While not illustrated in detail, the wireless communication network may include components typical of most cellular networks, such as one or more base stations 112, mobile switching centers 114, home location registers (not shown), visitor location registers (not shown), wireless network databases (not shown), etc. An example of the frequencies on which channels of the mobile telecommunication network may operate include the typical American cell phone frequencies, which start at 824 MHz and end at 894 MHz.

[0022] The wireless telecommunication network 102 may also include various wired or partially wired networks, such as the Internet, a wired LAN (local area network), or even a public switched telephone network (PSTN). While not all types of networks are described here, aspects of the invention may be implemented within the framework of many types of networks (e.g., satellite, etc.). Because the extent of the typical wireless telecommunication network 102 is extremely large, effective communication ranges of thousands of miles may be practical. Furthermore, most wireless telecommunication networks are designed for low latency to support human voice-based conversation. This low latency enables fast system reaction time, even when nodes are located on opposite sides of the earth.

[0023] While not shown in detail in Figure 1, in some embodiments, one or more of the three basic classes of devices (UAV 108, mobile device 104, computer/supporting device 106, or their hybrid derivatives such as cellular enabled PDA) may be connected to the cellular network indirectly via an RF-to-network bridge. Using the network-bridge configuration allows an aircraft to operate outside a cellular coverage area, but still be controlled by a mobile ground station or PC directly connected to the network. Alternatively, a PC may be operated from outside the cellular network to control a UAV operating within the network.

[0024] Many communication patterns are possible within the mesh network 110. For example, the mesh network 110 may facilitate aircraft-to-mobile device communication, where a user of the mobile device 104 (located on the ground and thereby comprising a ground control station) inputs commands into the mobile device 104 to control the aircraft/UAV 108 or access data collected by systems onboard the aircraft/UAV 108. In another example, the mesh network 110 facilitates aircraft-to-aircraft communication, which enables scenarios such as target handoff, collision avoidance, separation assurance, and flock behaviors. Where a more sophisticated user interface (UI) environment is desired than is typically available with a small mobile device, the mesh network 110 may support aircraft-to-computer communication, which may occur via the wireless network and/or via a wired network, such as the Internet. For example, a supporting technology 106 comprising a PC may have direct or indirect access to the wireless telecommunication network (e.g., via a network bridge) so that it operates as a stand-in for a mobile wireless device on the network.

[0025] Scenarios may also exist in the control of UAVs where a first user of a first mobile device wishes to communicate directly with a second user of a second mobile device (e.g., to communicate regarding a joint aircraft control strategy). Accordingly, the mesh network 110 can be used for mobile-to-mobile communication, which can be text- or even voice-based. Computer-to-computer communication may also be used in a similar context, where, for example, a PC or other supporting technology 106 is used as a stand-in for a mobile device on the wireless telecommunication network 102, for example, via an RF-to-network bridge.

[0026] The mesh network 110 may be utilized for communication from a mobile device 104 to a computer 106, for example, in contexts such as chat and target

hand-off. Mobile device-to-computer communication may also be used when transferring information between a mobile device 104 and a computer or other supporting device 106. For example, this communication pattern may be used in the case where the mobile device 104 is used to establish a communication link with the UAV 108 but where a user interfaces with the computer/supporting device 106 when he or she needs a more robust user interface to, for example, input more complex control instructions or view graphically rich information transmitted from the UAV 108.

[0027] In some embodiments, a UAV 108 may operate outside the physical extent of a telecommunication network 102, for example, by communicating (e.g., via a proprietary communications system) with a ground station PC that is, itself, connected to the wireless telecommunication network 102. This configuration enables remote control of the UAV 108 by one or more mobile devices 104 within the wireless telecommunication network, even though the UAV 108 itself is outside the physical telecommunication network 102. In another embodiment, a UAV (e.g., instead of a ground station) serves as the bridge to the network. Thus, in this scenario, one aircraft 108 operating within range of the wireless telecommunication network 102 enables the controlling of an aircraft outside that range using mobile devices 104 within the wireless telecommunication network 102. Similarly, a UAV 108 may operate as a "cell tower" to dynamically extend the coverage area of a wireless telecommunication network 102.

[0028] In some embodiments, multiple simultaneous (or near simultaneous) calls are used between nodes within the mesh network 110. For example, multiple mobile devices can establish communication links with a single UAV, which can then stream different aspects of information to each mobile device. These aspects of information can eventually be consolidated back into a single data stream (e.g., for display at a computer). This multi-call configuration provides increased bandwidth (e.g., as may be required to pass full size and full frame rate digital video from a UAV 108 to a supporting device 106). Another way in which multiple calls can be used simultaneously (or near simultaneously) is to enhance composite link reliability. These calls can be routed through different base stations in the wireless telecommunication network 102 so that techniques for dynamic selection of the best quality link may be employed.

[0029] Figure 2 is a block diagram showing an example of a mobile wireless device, such as the mobile wireless device 104 of Figure 1. While a mobile phone is shown as the mobile wireless device 104 in Figures 1 and 2, those skilled in the relevant art will appreciate that the invention can be practiced with other devices and configurations, including mobile Internet appliances, hand-held devices, wearable computers, multi-processor systems, microprocessor-based or programmable consumer electronics, set-top boxes, PDAs, portable laptop computers, and the like. The term "mobile device" is intended to include all such devices.

[0030] The mobile device 104 has one or more internal or external antennas 202 for receiving and transmitting electromagnetic signals such as radio frequency signals. A transceiver 204 is connected to the antenna(s) 202 and typically provides modulation and demodulation of the transmitted and received signals, respectively. A processor unit 206 connected to the transceiver 204 may comprise a signal processor, microprocessor, ASIC, or other control and processing logic circuitry. The processor unit 206 may perform signal coding, data processing, input/output processing, power control, and other functions necessary for implementing a mobile communication device. A user (e.g., aircraft control personnel) may provide input to the processor unit 206 via a keypad 208, microphone 210, or display/touchpad 212. In turn, the processor unit 206 may provide information to the user via the display/touchpad 212 or a speaker 214.

[0031] The processor unit 206 may access information from, and store information in, a nonremovable memory 216 or a removable memory 218. The nonremovable memory 216 may consist of RAM, ROM, a hard disk, or other well-known memory storage technologies. The removable memory 218 may consist of Subscriber Identity Module (SIM) cards, which are well known in GSM communications systems, or other well-known memory storage technologies, such as "smart cards." Generic applications 220 such as wireless content browser applications and address book applications may be implemented in either the removable memory 218 or the nonremovable memory 216. The removable memory 218 and/or nonremovable member 216 may also be configured or programmed (e.g., using a mobile version of Java or in C/C++ on a mobile version of Linux) to support complex user interfaces and full color graphics. The removable memory 218 and/or nonremovable member 216 may also be configured or programmed to

run an application (e.g., a Java program) that provides an aircraft and/or payload control and visualization, which may include functionality such as a moving, zoomable map. Alternatively, the mobile device 104 may be configured to have only a limited input interface and passively display relayed imagery.

[0032] Figure 3 is a block diagram showing an example of control components of a UAV, such as the UAV 108 of Figure 1. In particular, the UAV may have several onboard components that allow it to be controlled via a wireless telecommunication network. The UAV may also have components associated with providing outgoing information. The outgoing information can include surveillance or aircraft monitoring information that can be transmitted back to a controlling device via a wireless telecommunication network. In some embodiments, some or all of these components may be associated with a consumer mobile device such as a camera-enabled cell phone, and thus, may be very similar to the components described with respect to the mobile device 104 of Figure 2. Any one of these components may also be incorporated onto the UAV separately (as opposed to being packaged within a typical mobile device), and then connected using technology such as a USB.

[0033] The components may include a transceiver and/or gateway component 304 that is connected to one or more antenna(s) 302 and provides modulation and demodulation of transmitted and received signals so that the UAV may communicate via the wireless telecommunication network. A processor unit 306 connected to the transceiver 304 may comprise a signal processor, microprocessor, ASIC, or other control and processing logic circuitry. The processor unit 306 may perform signal coding, data processing, input/output processing, power control, and other functions necessary for implementing mobile communication onboard the UAV. Whether included on the mobile device or as a separate component, the processor unit 306 may take on several roles beyond "just" a communications processor. For example, it may be utilized as a flight computer, a mission computer, a navigation computer, or a video processor/preprocessor. The processor unit 306 may access information from, and store information in, memory 310, which can be a nonremovable memory or a removable memory (e.g., SIM card). Various generic and specialized applications 320 may be configured or programmed in memory as needed.

[0034] Cameras 312, including motion and/or still cameras (which are often now included on aftermarket mobile devices such as a picture phones), may replace

more traditional imaging sensors on the UAV, thus providing an ultra compact ISR (intelligence, surveillance, and reconnaissance) UAV. For example, the mobile device's motion or still camera may be used to "see and avoid" other aircraft, or for imaging ground objects.

[0035] A microphone component 316, such as found in the typical cell phone, may be used to perform diagnostics, such as monitoring the UAV's engine health. This health monitoring information can then be passed via a voice channel to a mobile device that is being used to control the UAV (such as a mobile device at a ground station). In some embodiments, a standard cell phone microphone is replaced with any other appropriate transducer on the aircraft, such as an accelerometer, for measuring UAV body vibration. This signal may also be passed to the controlling mobile device over a voice channel or even a data channel of the telecommunication network. The microphone 316 may also be used to acquire aircraft telemetry or sensor data for transmission over the wireless communication link.

[0036] A speaker component 314, such as found in the typical cell phone, may be amplified and used like a public address system. In some scenarios, this may allow a remote human to talk to people within the field of view of the UAV camera, while remaining safely away from the area. In a military context, the speaker component 314 (or another mobile device-related component) on the UAV may be used to safely trigger improvised explosive devices (IEDs), by flying along roads and making calls. For example, the UAV may call the cell phone trigger on an enemy IED to trigger safely.

[0037] If equipped with mobile device components allowing it to perform assisted global positioning (AGPS), the AGPS function 318 may be used for UAV navigation via, for example, CDMA pilot tone measurements or actual GPS measurements. This provides an improvement in interference rejection compared to a stand-alone GPS receiver.

[0038] If the UAV is equipped with mobile device components allowing it to function as a "cell tower," the UAV may be configured to selectively place or block calls (e.g., for strategic purposes). The UAV may also be used to "sniff" the cell call activity for unauthorized calls in controlled areas, such as in war combat zones.

[0039] Figure 4 is a block diagram showing an example of a computer 400, such as the supporting technology/computer 106 of Figure 1, which may also be used to control the UAVs via the mobile telecommunication network. As with most conventional computers, the computer 400 may include a processing unit 402, a system memory 404, and a system bus 406 that couples various system components including the system memory to the processing unit. The processing unit 402 may be any logic processing unit, such as one or more central processing units (CPUs), digital signal processors (DSPs), application-specific integrated circuits (ASIC), etc. Unless described otherwise, the construction and operation of the various blocks shown in Figure 4 are of conventional design. As a result, such blocks need not be described in further detail herein, as they will be readily understood by those skilled in the relevant art.

[0040] The system bus 406 can employ any known bus structures or architectures, including a memory bus with memory controller, a peripheral bus, and a local bus. The system memory 404 includes random access memory ("RAM") 408 and read-only memory ("ROM") 410. A basic input/output system (I/O) 412, which can form part of the ROM 410, contains basic routines that help transfer information between elements within the computer 400, such as during start-up. The hardware elements of the input/output system 412 allow a user to enter commands and information into the computer 400 through input devices such as a keyboard, a pointing device such as a mouse, or other input devices including a microphone, joystick, game pad, scanner, etc. (all not shown). These and other input devices are connected to the processing unit 402 through an interface such as a serial port interface that couples to the bus 406, although other interfaces such as a parallel port, game port, or universal serial bus ("USB") can be used. For example, other hardware devices, such as a PCMCIA reader that receives a card, can be coupled to the interface. A monitor or other display device is coupled to the bus 406 via a video interface, such as a video adapter. The computer 400 can include other output devices, such as speakers, printers, etc.

[0041] The computer 400 also includes a hard disk drive 414 for reading from and writing to a hard disk (not shown), and an optical disk drive 416 and a magnetic disk drive 418 for reading from and writing to removable optical disks 420 and magnetic disks 422, respectively. The optical disk 420 can be a CD-ROM, while the

magnetic disk 422 can be a magnetic floppy disk. The hard disk drive 414, optical disk drive 416, and magnetic disk drive 418 communicate with the processing unit 402 via the bus 406. The hard disk drive 414, optical disk drive 416, and magnetic disk drive 418 may include interfaces or controllers (not shown) coupled between such drives and the bus 406, as is known by those skilled in the art. The drives 414, 416, and 418, and their associated computer-readable media, provide nonvolatile storage of computer-readable instructions, data structures, program modules, and other data for the computer 400. Although the depicted computer 400 employs a hard disk, optical disk 420, and magnetic disk 422, those skilled in the relevant art will appreciate that other types of computer-readable media that can store data accessible by a computer may be employed, such as magnetic cassettes, flash memory cards, digital video disks ("DVD"), Bernoulli cartridges, RAMs, ROMs, smart cards, nanotechnology memory, etc.

[0042] Program modules can be stored in the system memory 404, such as an operating system 424 and other application programs 426 that enable the control of UAVs and that allow for data received from UAVs to be readily accessed in a convenient format. The system memory 404 may also include a web browser 428 for permitting the computer 400 to access and exchange data with web sites in the World Wide Web of the Internet. The application programs 426 may have access to one or more databases, which may be internal or external to the computer. For example, the computer may have access to a map database 430 (which stores maps for areas where UAVs are operated), a combat plans database 432 (which stores combat plans for UAVs operating in a military context), and multiple other input source databases 434.

[0043] The computer 400 can operate in a networked environment using logical connections to one or more remote computers, such as a remote computer 450. For example, the computer 400 may be involved in performing a first set of tasks in a workflow and the remote computer 450 may be involved in performing a second set of tasks in the workflow. In another example, the remote computer 450 offers an input source for a workflow facility hosted at the computer 400. Likewise, the computer 400 may be involved in designing workflows having tasks to be performed by the remote computer 450. Like the computer 400, the remote computer 450 can be a personal computer, a server, a router, a network PC, a peer device, or other

common network node, and typically includes many or all of the elements described above for the computer 400. Typically, the remote computer 450 includes a memory storage device such as a disk drive 452. The remote computer 450 may be logically connected to the computer 400 via any known method that permits computers to communicate, such as through a local area network ("LAN") 454 or a wide area network ("WAN") or Internet 456. Such networking environments are well known in offices, enterprise-wide computer networks, intranets, and the Internet.

[0044] In a LAN networking environment, the computer 400 is connected to the LAN 454 through an adapter or network interface (coupled to the bus 406). When used in a WAN networking environment, the computer 400 often includes a modem or other device for establishing communications over the WAN/Internet 456. In a networked environment, program modules, application programs, or data, or portions thereof, can be stored in the remote computer 450, such as in the disk drive 452. Those skilled in the relevant art will readily recognize that the network connections shown in Figure 4 are only some examples of establishing communication links between computers, and other links may be used, including wireless links. In general, while hardware platforms, such as the computer 400 and remote computer 450, are described herein, aspects of the invention are equally applicable to nodes on a network having corresponding resource locators to identify such nodes.

III. System Flows

[0045] Figures 5 through 8 are representative flow diagrams that show processes that occur within the environment of Figure 1. These flow diagrams do not show all functions or exchanges of data but, instead, provide an understanding of commands and data exchanged under the system. Those skilled in the relevant art will recognize that some functions or exchanges of commands and data may be repeated, varied, omitted, or supplemented, and other aspects not shown may be readily implemented. For example, while not described in detail, a message containing data may be transmitted through a message queue, over HTTP, etc.

[0046] Figure 5 is a flow chart showing an example of a routine 500 performed at a mobile device used for controlling a UAV. For example, the mobile device may be a mobile phone configured as a ground control station, which can be operated by

a user to send control signals to the UAV and/or receive data back from the UAV, such as monitoring and surveillance data.

[0047] At block 501, the routine 500 sets up a wireless communication link with the UAV on the wireless communication network. For example, this may include communication (e.g., via a control channel) with a mobile switching center that is associated with the wireless communication network. As a result of this communication, both the mobile device and the UAV may receive channel assignment information from the mobile switching center that permits access to one or more channels of the wireless communication link, including one or more voice channels and/or data channels. At block 502, the routine 500 receives the channel assignment information, thereby establishing an active communication link via one or more designated communication channels. At block 503, the routine 500 sends control signals to the UAV (e.g., instructions to control the activities of the UAV, including its direction and speed of travel, weapons discharge, etc.) and/or receives data back from the UAV (e.g., surveillance information, video information, UAV health monitoring information, etc.). The format and types of information communicated via the established communication link may include voice (or other audio) data, image data, video data, binary data, text data, etc., depending on system and network configurations. At block 504, assuming the session with the UAV has ended (e.g., the UAV has safely landed), the routine 500 terminates the communication link, thereby ending the UAV session.

[0048] Figure 6 is a flow chart showing an example of a routine 600 performed by a collection of one or more components onboard a UAV, which enable the UAV to communicate via a wireless telecommunication network. For example, the collection of components may be packaged together as a mobile device, such as a cell phone, which is connected to other control and/or surveillance systems of the UAV (e.g., via a connection such as a USB bus).

[0049] At block 601, the routine 600 receives channel assignment information for establishing a wireless communication link with a control device (such as a ground-based mobile telephone) via the wireless telecommunication network. For example, this may involve communication (e.g., via a control channel) with a mobile switching center associated with the wireless communication network to receive channel assignment information relating to one or more voice channels and/or data

channels. At block 602, the routine 600 establishes an active communication link via the one or more channels. At block 603, the routine 600 receives control signals (e.g., instructions to control the activities of the UAV, including its direction and speed of travel, weapons discharge, etc.) sent from the ground-based mobile telephone. In addition or alternatively, at block 603 the routine 600 may send data (e.g., surveillance information, video information, UAV health monitoring information, etc.) back to the ground-based mobile control device. The format and types of information communicated via the established communication link may include voice (or other audio) data, image data, video data, binary data, text data, etc., depending on system and network configurations. At block 604, assuming the session with the UAV has ended (e.g., the UAV has safely landed) the routine 600 receives a termination signal for terminating the communication link, thereby ending the communication session.

[0050] Figure 7 is a flow chart showing an example of a routine 700 performed by a computer that is capable of establishing a wireless communication link (via a wireless telecommunication network) to control one or more UAVs or, alternatively, a computer that can establish a connection (e.g., wireless, wired, Bluetooth, infrared, etc.) to a mobile wireless communication device that is, in turn, used to communicate with one or more UAVs via the wireless telecommunication network. In either scenario, the computer allows for a robust user interface from which a user can easily provide control commands to a UAV, monitor the UAV, and/or receive data feeds (e.g., video surveillance, imagery, health monitoring, etc.) from the UAV.

[0051] At block 701, the routine 700 receives control input from a user wishing to control the UAV via an interface provided by an application running at the computer. At block 702, the routine 700 establishes either an indirect or direct connection with the UAV. For example, the computer may be able to establish a WAN-type connection with components of the wireless telecommunication network (e.g., base station and mobile switching center), so that the computer can communicate as a stand-in for a traditional wireless communication device, thereby connecting more or less directly with the UAV via a partially wireless connection. In another arrangement, the routine 700 may establish a communication link (wired or wireless) with a mobile device that can, in turn, communicate with the UAV via a wireless connection, such as is described with respect to Figure 5. At block 703, the

routine 700 sends control input to the UAV (or the intermediary mobile device) at least in part via the wireless communication network. At block 704, the routine 700 receives surveillance and/or monitoring data from the UAV (or via the intermediary mobile device) at least in part via the wireless communication network. The routine 700 then ends.

[0052] Figure 8 is a flow chart showing an example of a routine 800 performed onboard an aircraft that is capable of forming a network bridge that enables communication of control devices with other aircraft, such as UAVs that are otherwise outside a mobile telecommunication network. In another example, the aircraft is a leading unit for a group of multiple aircraft that are each configured to perform joint aerial maneuvers (e.g., led by the leading unit).

[0053] At block 801, the routine 800 establishes a wireless connection with a ground control device (such as a wireless telecommunication device at a ground station or a PC) via the mobile telecommunication network. Examples of establishing such a wireless connection were described in more detail above with respect to Figure 5 and 7. At block 802, the routine 800 establishes a communication link with one or more UAVs (e.g., UAVs that are outside the telecommunication network or UAVs that are part of a group of multiple aircraft that are configured to perform joint aerial maneuvers). This connection may be via the mobile telecommunication network or via some other form of wireless communication (e.g., direct RF, infrared, Bluetooth, etc.). At block 803, the routine 800 receives control signals from the ground control device. At block 804, based on the received control signals, the routine 800 passes along appropriate control signals to the one or more UAVs. Block 804 of the routine 800 may also be reversed so that the UAV receives data from the one or more UAVs to pass back to the ground control station. The routine 800 then ends when the control session ends or when the communication session is otherwise terminated.

IV. Conclusion

[0054] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the invention. For example, while certain telecommunication networks are described with respect to various

embodiments, aspects of the invention may be implemented on a variety of wireless networks. Other aspects that may vary include the type and makeup of devices used to control UAVs, as well as the systems on board the UAVs themselves. Aspects of the invention described in the context of particular embodiments may be combined or eliminated in other embodiments. Further, while advantages associated with certain embodiments of the invention have been described in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

CLAIMS

I/We claim:

1. A method for controlling an unmanned aerial vehicle (UAV), the method comprising:
 - using a wireless device to send a control message to a receiver at the UAV, wherein the wireless device communicates with the receiver via a wireless network configured primarily for mobile telephone communication; and
 - using the wireless device to receive communications from a transmitter at the UAV, wherein the wireless device receives the communications from the transmitter via the wireless network.
2. The method of claim 1 wherein sending the control message includes sending a message including instructions to control surveillance activities of the UAV.
3. The method of claim 1 wherein sending the control message includes sending a message including instructions to control the velocity and direction of the UAV.
4. The method of claim 1 wherein sending the control message includes sending a message including instructions to control the activity of weapons systems on the UAV.
5. The method of claim 1 wherein sending the control message includes sending a message including instructions to control takeoff and/or landing of the UAV.
6. The method of claim 1, further comprising establishing an ongoing connection between the wireless device and the receiver.

7. The method of claim 1 wherein using the wireless device to receive communications from a transmitter includes receiving compressed digital video transmissions.

8. The method of claim 1 wherein using the wireless device to receive communications from a transmitter includes receiving full size and full frame rate digital video transmissions.

9. The method of claim 1 wherein using the wireless device to receive communications from a transmitter at the UAV includes using the wireless device to receive surveillance information collected by the UAV.

10. The method of claim 1 wherein using the wireless device to receive communications from a transmitter at the UAV includes using the wireless device to receive health and/or status information associated with the UAV.

11. The method of claim 1 wherein using the wireless device to receive communications from a transmitter at the UAV includes using the wireless device to receive surveillance information collected by the UAV, wherein the collected information includes information associated with a second UAV and is collected for the purpose of avoiding airspace conflicts, conducting joint surveillance of a geographical area, and/or conducting joint tracking of a subject.

12. The method of claim 1 wherein the sending and receiving are performed from an aircraft other than the UAV.

13. The method of claim 1 wherein the sending and receiving are performed from a ground station.

14. A system for controlling unmanned aircraft comprising:
at least one ground control device having a transmitter configured for operation in a wireless communication network used primarily for mobile telephone communication; and

an unmanned aerial vehicle (UAV) including a mobile device having a receiver configured for operation in the wireless communication network, wherein the UAV is responsive to communications from the at least one ground control device, including communications received via the receiver.

15. The system of claim 14 wherein the UAV includes a bridging control system including a controller configured to relay control signals to one or more UAVs that are outside the range of the wireless communication network.

16. The system of claim 14 wherein the at least one ground control device includes multiple ground control devices, and wherein the transmitters associated with the multiple ground control devices are configured to send out, in parallel, multiple call signals usable to communicate with the UAV.

17. The system of claim 14 wherein the at least one ground control device includes a mobile telephone.

18. The system of claim 14 wherein the at least one ground control device includes a cellular telephone.

19. The system of claim 14 wherein the at least one ground control device includes a cellular enabled personal digital assistant (PDA).

20. The system of claim 14 wherein the ground control device includes a personal computer configured for wireless communications.

21. The method of claim 14 wherein the mobile device at the UAV includes a mobile telephone.

22. The system of claim 14 wherein the mobile device at the UAV includes a cellular telephone.

23. The system of claim 14 wherein the mobile device at the UAV includes a cellular enabled personal digital assistant (PDA).

24. The system of claim 14 wherein the mobile device at the UAV includes a personal computer configured for wireless communications.

25. The system of claim 14 wherein the at least one ground control device is linked directly to the wireless communication network and wherein the mobile device at the UAV is linked to the wireless communication network indirectly via an RF-to-network bridge.

26. The system of claim 14 wherein the wireless communication network includes a cellular telephone network.

27. A system on an unmanned aerial vehicle (UAV), the system comprising:

- a mobile communication device configured for communication via a network that is used primarily as a consumer voice and data communication network, the mobile communication device including:

- a mobile device application configured for communication with at least one device at a ground control center;

- a receiver configured to receive signals from the ground control center;

- a transmitter configured to send signals from the mobile communication device; and

- an antenna; and

- a control application responsive to signals received at the mobile communication device.

28. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes a global system for mobile communications (GSM) network.

29. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes a general packet radio service (GPRS) network.

30. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes a code division multiple access (CDMA) network.

31. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes an evolution-data optimized (EV-DO) network.

32. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes enhanced data rates for GSM evolution (EDGE) network.

33. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes a third generation global system for mobile communications (3GSM) network.

34. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes a digital IS-136/time division multiple access (IS-136/TDMA) network.

35. The system of claim 27 wherein the mobile communication device is configured for communication with a network that includes an integrated digital enhanced network (iDEN).

36. The system of claim 27, further comprising a data collection system configured for producing output signals for transmission to the ground control center, wherein the transmission of the output signals occurs via the mobile communication device over the network.

37. A system on an unmanned aerial vehicle (UAV), the system comprising:

at least one telecommunication device including a transceiver configured for communication via a wireless telecommunication network;
a control system including at least one software application for controlling at least one of surveillance actions and maneuvering actions of the UAV based on control actions communicated through the at least one telecommunication device; and
a connection that links the at least one telecommunication device to the control system.

38. The system of claim 37 wherein the at least one telecommunication device is linked to a computer having an interface to receive input for controlling the UAV.

39. The system of claim 37 wherein the at least one telecommunication device is associated with a cellular telephone.

40. The system of claim 37 wherein the at least one telecommunication device is linked to a computer having an interface to receive input for controlling the UAV, and wherein the computer is outside the wireless telecommunication network.

41. The system of claim 37 wherein the at least one telecommunication device and the control system function together as a base station to dynamically extend the coverage area of the wireless telecommunication network.

42. A method for controlling an unmanned aerial vehicle (UAV), the method comprising:

communicating with a mobile telephone switching center via a control channel associated with a wireless telecommunication network to establish a wireless communication link, including:

receiving a channel assignment that permits access to a designated channel of the wireless telecommunication network; and
sending control signals to the UAV via the designated channel, wherein the control signals are used to control the actions of the UAV.

43. The method of claim 42, further comprising receiving data signals from the UAV via the designated channel.

44. The method of claim 42 wherein the wireless telecommunication network is associated with control channels, voice channels, and data channels, and wherein the designated channel is a data or voice channel.

45. The method of claim 38 wherein the designated channel is associated with a frequency between 824 and 849MHz.

46. At an unmanned aerial vehicle (UAV) a method for receiving control instructions from a remote source, the method comprising:

receiving an indication of a channel assignment from a mobile switching center, wherein the indication is received via a control channel associated with a wireless communication network, and wherein the channel assignment permits access to at least one designated channel of the wireless communication network; and
receiving control signals from the remote source via the at least one designated channel, wherein the control signals are used to control the actions of the UAV.

47. The method of claim 46, further comprising sending data signals from the remote source via the at least one designated channel.

48. The method of claim 46 wherein the at least one designated channel is associated with a frequency between 824 and 849MHz.

49. The method of claim 46, further comprising generating additional control signals for receipt by one or more additional aircraft, wherein the additional aircraft are part of a joint operational group led by the UAV.

50. The method of claim 46, further comprising generating additional control signals for receipt by at least one additional aircraft, wherein the additional aircraft is out of the range of the wireless communication network.

51. A method for remotely controlling an unmanned aircraft, the method comprising:

communicating with a control node in a wireless telecommunication network to establish a communication link with the unmanned aircraft, wherein the communication link includes a wireless communication channel that permits the unmanned aircraft to communicate with at least one node of the wireless telecommunication network; and

sending control signals to the aircraft, at least in part, via the established communication link, wherein the control signals are used to control the actions of the aircraft.

52. The method of claim 51 wherein communicating with the control node is performed via a non-wireless network connection.

53. The method of claim 51 wherein the communication link further includes a non-wireless aspect that permits access to the at least one node of the wireless telecommunication network.