

Dr. Babu Devnarayan Choudhary

Email: bdc@thinkclock.com , b.choudhary@imperial.ac.uk ; Tel (M): +44 (0)7517 581192

Homepage: <https://www.linkedin.com/in/bdevnarayan/> ; <http://thinkclock.com/bdc>

Address: 17, Cranston Close, Hounslow, Greater London TW3 3DQ ; **Work Permit: Not Required (UK ILR)**

Profile Summary:	<ul style="list-style-type: none"> ❖ In-depth understanding of communication systems especially Physical Layer (Transceiver Architecture, Antenna Theory, RF propagation, LTI systems etc.). ❖ Strong implementation experience of Analog/Digital Signal Processing related to Noise Filtering, Spectral Analysis, Beamforming, Localization, RADAR, MIMO, Modulation/Demodulation etc. along with Electromagnetic Modelling. ❖ Over 10-year experience of building complex embedded systems from prototyping to deployment involving sensors, actuators and wireless components (Cellular, LPWAN, VHF, SDR etc.) with various processor boards. ❖ Wholistic understanding of system design involving trade-offs related to cost, performance, energy consumption etc. in-tune with the business logic. ❖ My two patented inventions - CogniSense™ and PhysioGram have been identified as transformative technologies by Imperial Innovations leading to a Spin-Out with over £200K funding already secured. 	
Education:	PhD [Aug.'11-Sep.'17]	Thesis: "Sensing without Sensors: Non-Intrusive methods for Cognitive Sensing" Department of Computing, Imperial College London, UK
	Graduation [2003-07]	B.Tech in Information Technology CGPI- 7.98/10.0 (3.2/4.0) Indian Institute of Information Technology, Allahabad, India
	XII: [2001] X : [1999]	84.31 % (Rajasthan Board, India) 83.17 % (Rajasthan Board, India)
Work Experience:	[Aug'2011- Today]	Research Assistant, AESE Group, Department of Computing, Imperial College London, UK
	[Sep'08- July'2011]	Founding Director & Research Engineer, ThinkClock Innovation Labs Pvt. Ltd., IIIT Allahabad, India
	[July'07-June'08]	Associate Software Engineer, (Information Security) SafeNet India Pvt. Ltd., Noida, India
	[Jan-July 2007]	Research Internship , (Information Security) LESTER Laboratory, University of South Brittany, Lorient, France
Achievements:		
<ul style="list-style-type: none"> ❖ Awarded £15,000 seed funding plus £150,000 follow-up funding by Imperial Innovations for developing my patented technology -CogniSense™ for commercial trials. ❖ Awarded £35,000 towards commercialization of my CogniSense™ invention through the "Techcelerate Programme 2018" by Imperial. ❖ Selected by Digital-Catapult to pitch CogniSense™ to Industry Audience at Smart Factory Expo 2017 in Liverpool, which resulted in numerous industrial collaborations (see link). ❖ Awarded 75,000 INR prize, as a winner of Next Big Idea Contest 2011 organized by Intel and Department of Science & Technology, Govt. of India in association with IIM Bangalore. ❖ Awarded 525,000 INR (approx. \$10,500) of initial funding from the TIDE scheme of Govt. of India for my ThinkClock Tactile project. ❖ Awarded 100,000 INR prize by Texas Instruments, as a winner in All India DSP design Contest 2006 for project "Collision Avoidance System for Smart Automobiles". ❖ Awarded French International Scholarship (1000 euro/month plus airfare) from EGIDE for final semester internship at LESTER Lab, UBS France. ❖ Awarded Honorable Mention (including \$300 prize and trip sponsorship to the award ceremony in San-Francisco) by 43rd Design Automation Conference (DAC 2006) for the paper 		

titled “Phase Delay based Collision Avoidance RADAR for Smart Automobiles”.

- ❖ Selected by **ISRO/ASI** as one of 20 semi-finalists from across India for International Astronautical Congress (IAC 2006) held at Valencia, Spain.
- ❖ **One of the 6-finalists** in Idea-to-Implementation 2008 -an All India Business Plan Competition held at IIM Calcutta.
- ❖ **One of the 8-finalists** in NIRVAAN 2007 -an All India Business Plan Competition held at IIM Lucknow.
- ❖ **KVPY-2004 Fellowship.** KVPY is a research program conducted by IISc Bangalore and funded by Department of Science and Technology, Government of India, in which about 20 students are selected from engineering stream every year.

Communication Skills:

- ❖ Involved in teaching Signal Processing to Masters Students at Imperial College London.
- ❖ Involved in marketing the research to industry audience through the commercialization activities of our CogniSense™ technology.
- ❖ Provided consultancy to **Syngenta** reflecting the role of IoT in precision agriculture.

Project Experience

S4: Science for Sensor Systems Software
Imperial College London
Sponsor: EPSRC
Time: Jan. 16-Sep. 17
Signal Processing: MATLAB-Simulink, Noise Filtering, Spectral Analysis, SNR Enhancement, MIMO Beamforming, WiFi-OFDM, Correlation, Classification and Localization based on basis functions.
Instruments: Software Defined Radio (USRP, RTL SDR) Handheld Spectrum Analyser, PC based Oscilloscope: Picoscope, RF Components: various antennas, gain/phase detectors, PLL, up/down convertors, RF switches, transmission lines, Directional Couplers, Impedance Transformers, RF power detectors, other components involved in Tx/Rx frontend.

This project: aims to develop a unifying model of IoT hardware and software in combination with the operational environment to provide a digitized replica of the whole system.

My role: has been to develop Non-Invasive methods to perform sensing using the RF signal. I have developed two new methods PhysioGram and CogniSense™ from concept to TRL-5, utilizing an in-depth understanding of Communication, Control, and LTI System’s Theory.

❖ **PhysioGram Patent:**

Babu D. Choudhary, Julie A. McCann, “A method and apparatus for Motional, Structural and Compositional characterization of a Physical System using Radio signal”. (In Process)

❖ **CogniSense™ Patent:**

Babu D. Choudhary, Julie A. McCann, “An apparatus and method for generating a motional signature indicative of motion of moving parts of a target machine”. (P109871PCT, Filing Date: 8 July 2016)

- ❖ Awarded **£15K** for Proof-of-Concept followed by **£150K** for further development of CogniSense™ by Imperial Innovations for commercial trials.

- ❖ **Impact:** trials of CogniSense™ are currently being setup with RS Components, Carillons, Romax InSight, GSK, BOC etc.

Civil Infrastructure Monitoring and Control
Imperial College London
Sponsor: EIT ICT Labs
Time: July 2015-Dec. 2015

Skills: Linux, RS232 Comport communication, Python script, TI Code Composer Studio (CCS), TI RF Studio.

This project: involved instrumentation of utility networks with IoT.

My role: I was the part of the connectivity team responsible for identifying the most appropriate LPWAN communication module for the urban environment. We have created a wireless testbed to evaluate various modules (**LoRa, NWave, XBee, Sigfox and TI CC430**), and deployed it around Imperial and Hyde Park to perform a comparative study.

Output: Publication

Sokratis Kartakis, **Babu D. Choudhary**, Alexander D. Gluhak,

<p>PCB design, power regulation, Antenna placements, Near-field effect, Electromagnetic Interference (EMI) mitigation, Spectrum Analyser, Field Experiments.</p>	<p>Lambros Lambrinos, and Julie A. McCann, “Demystifying low-power wide-area communications for city IoT applications”, In <i>Proceedings of the Tenth ACM International Workshop on Wireless Network Testbeds, Experimental Evaluation, and Characterization</i> (WiNTECH '16).</p>
<p>CubeSat: Adaptive communications and resource management for very large scale/very low-cost space systems Imperial College London Sponsor: UK Space Agency Time: Feb. 2015-July 2015 Skills: TI CCS Studio, RTOS, TI RF Studio, Energia, Wireless MCU CC4305137 with multi-band radio, solar cells, Indoor Emulation of the test environment.</p>	<p>This: was an exploratory project to assess the feasibility of Thin-Film based IoT devices which are battery-free and solar powered. Such ultra-light, ultra-small, ultra-cheap and ultra-low-powered satellites could be a low-cost alternative for space exploration using a CubeSat class payload.</p> <p>My Role: considering that any microchip circuit can be converted into a Thin-Film version, I have developed Adaptive and Predictive task scheduling algorithms with insight from off-line task profiling and solar-cell characteristics in order to optimize the performance of a swarm of micro-satellites in terms of its longevity and connectivity under the uncertainty of space weather.</p>
<p>FUSE: Floodplain Underground Sensor Network Imperial College London Sponsor: NERC Time: Aug. 2011-Jan. 2015</p> <p>Lab Equipment: Oscilloscope, Logic Analyzer, Vector Analyzer</p> <p>Processor: ARM Processor Board, Arch Linux, C/C++, multi-threading, interrupts for wake-up, communication interfaces -SPI, I2C, UART etc.</p> <p>Peripherals: ADC/Relay Board, Real Time Clock, SD Card, Sensor excitation circuit, MOSFET switch, GPIO etc.</p> <p>Wireless Modules: ISM band transceivers of different frequencies (Radiometrix: 173MHz, 433MHz, 458MHz and 869MHz) with different Tx power levels (0-500mW), licensed-band VHF module (Warwick X8200 5-Watt), SIMCOM GSM/GPRS modem, Adaptive MAC layer, Communication through cellular network using AT commands for SMS, Call, UDP, TCP, HTTP, FTP, Email etc..</p>	<p>This project: was aimed to deploy an Underground Wireless Sensor Network in a floodplain along the Thames river for soil and vegetation monitoring in-order to quantify the hydro-ecological interactions.</p> <p>My role: This was in collaboration with soil and environmental scientists, but I was solely responsible for the technology development from requirement-capturing to deployment with following activities involved.</p> <ul style="list-style-type: none"> ❖ Field experiments related to wireless communication through soil with various ISM band radio modules in different configurations under different soil conditions. ❖ Evaluating various environmental sensors (Temperature, Conductivity, Moisture, Water-Potential etc.) to find best options. ❖ Antenna Physics, Electromagnetic Modelling using MATLAB, understanding RF propagation through soil-water, Link-budget analysis, understanding energy flow from Battery >> Radio >> Transmission line >> Antenna >> Medium, the impact of the medium on the radio. ❖ Node Design optimization considering the trade-offs around power consumption, longevity, size, cost, complexity etc., Building an IoT device from scratch by integrating appropriate components. ❖ Extensive exposure of dealing with electronic circuits in the lab as well as in the field in extreme environments troubleshooting issues related to power, component failure, clock drift, EMI, interference, integrity issues, connectors, packaging etc. ❖ Network topology planning, adaptive routing algorithms, Lifetime analysis, communication between cellular-gateway and cloud-server, over the air-updates.

<p>Sensors:</p> <p>Digital-Output- Decagon-5TE, Decagon MPS-6, SENSIRION - SHT75. Analog Output: Vegetronix VG400, IMSL Water Table Sensor</p>	<p>Notable Outputs:</p> <ul style="list-style-type: none"> ❖ Sensing without Sensors: by monitoring the radio itself. ❖ Saving idle state energy drainage (> 70%) by using a boot-up timer. ❖ SleepSense: ultra-low-power ambient and accumulative sensing in a sleep state by replacing Crystal Oscillator with a customized sensor-coupled oscillator.
<p>Remote Energy Metering System ThinkClock Innovation Labs Time: Sep. 2009-July 2011</p> <p>Role: Technology Lead</p> <p>Skills: MCU: Microchip PIC8F8722, GSM/GPRS: SIMCOM 300 module, ZigBee: Microchip MRF24J40MA, Metering IC MCP3909, Microchip IDE and C18 Compiler</p>	<p>Project: involves analog instrumentation of current & voltage sensing with temper protection mechanism and calculation of energy consumption in the load using MCU. Data from sensors of each phase are multiplexed into one SPI port of MCU. The controller MCU is interfaced with GSM/GPRS module through UART port and ZigBee & ethernet module through SPI ports. The energy consumption data is communicated to a central server (listening TCP, UDP or HTTP) periodically or on-demand through GSM/GPRS or pluggable ethernet in combination with ZigBee wireless mess network. A mechanism for two way communication with the meter is being developed using BOSH/SIP protocols.</p>
<p>Automotive Telematics System for Remote Tracking & Monitoring ThinkClock Innovation Labs Time: July 2009-July 2011</p> <p>Role: Technology Lead</p> <p>Skills: Java: J2SE, Servlet, JSP, J2ME, MySQL, SQL Toad, XML, Google Maps API: static/dynamic, Eclipse J2SE/J2EE, EclipseME, Mobile Tools for Java (MJT), JUnit, J2MEUnit, Sun Wireless Toolkit, Apache Tomcat, JDBC, Java SMS</p>	<p>My role: As a cofounder of the company, I was leading the product development team consisting of 7 people in close coordination with the marketing team. The project involved following modules.</p> <p>(1). Automotive Telematics Unit: This H/W device was based on Siemens XT65 GPS/GPRS module with Java IMP profile.</p> <p>(2). Telematics Engine: This is a S/W component running on the server responsible for receiving, parsing, interpreting the data using GIS coming from Automotive Telematics Unit via the cellular network. It supports TCP, UDP, HTTP, SMTP and SMS protocols for receiving data packets.</p> <p>(3). User Presentation Module: This is a client-side S/W module using which user can connect to the Telematics Engine and locate & track vehicle on the GIS map with complete history. It is a Web-based Tracking client for PC users: a servlet fetching Google Maps using Javascript.</p>
<p>SIP Mediator Client for routing audio/video from IP Camera to Asterisk PBX Server ThinkClock Innovation Labs Time: June. 2008-July. 2009</p> <p>Role: Software Developer</p> <p>Skills: Linux, Asterisk PBX Server, SIP, codec conversion, Ekiga SIP Client, TCP/IP, UDP, HTTP</p>	<p>The project: involved routing of audio/video data from an IP Camera (acting as a TCP/UDP/HTTP server) to an Asterisk PBX Server (Open source Telephony server compatible with SIP clients) by developing a Mediator SIP client on linux. The implementation was accomplished by me through inter-process communication (through shared memory access & semaphores) where one process retrieves audio/video data from IPCAM writing into a shared memory and other process fetching that data from shared memory to Ekiga SIP client (which routes to Asterisk). It also involved conversion of audio/video codecs because of compatibility reasons.</p>

<p>Software License Management System SafeNet India (Now Gemalto) Time: July 07-June 08</p> <p>Role: Software Developer</p> <p>Skills: C, C++, SQL, OpenSSL, Cryptographic Algo's (AES, RSA, ECC, SHA-1, SHA-2, HMAC), Design Documentation (FDD)</p>	<p>The project: involved development of Software license management system targeted for software vendors to enable them to protect their applications using our client API and license management server.</p> <p>I was responsible for design and development of Crypto-Layer to secure the communication between client and server in this project. During this project I explored and used various symmetric and asymmetric crypto-algorithms (AES, ECC, RSA, SHA, HMAC etc) and crypto tools like OpenSSL.</p>
<p>Hardware Implementation of ECC and RSA algorithms on FPGA LESTER Labs, UBS France Time: Jan 07-July 07</p> <p>Role: Internship</p> <p>Skills: C, C++, MS Visual Studio, Nios IDE, SOPC Builder, VHDL, OpenSSL, Cryptographic Algo's (AES, RSA, ECC, SHA-1, SHA-2, HMAC)</p>	<p>This project: involved hardware implementation of ECC along with RSA to speed-up and enhance the security of public key crypto-systems using Altera FPGA and Nios II soft processor. Programming was done in C++ and then the code was built for target hardware (Altera FPGA) using Altera IDE. During this project, I have developed a new side-channel resistant ECC point multiplication algorithm. The computationally intensive part of the code (ECC point multiplication and addition) was implemented in hardware using VHDL.</p>
<p>Other Interests:</p>	
<p>Volunteering for Social Care, Promoting Sustainable Agriculture in India, Yoga-Meditation</p> <p>Co-Founder: Mera Gaon (https://www.facebook.com/meraga0n/)</p> <p>This is a social engineering project which aims to raise the sensitivity and awareness of people towards our environment. We are developing aeroponic trees for roof-top gardens, with complete digital automation, which are cloud-connected and self-managed. This is an attempt to bring plants closer to people so that they can develop an intimate connection with them in their hearts and minds.</p>	