Personal campus e-mobility in NTU - the ebi

Executive Summary

- Showcase NTU as a sustainable campus (at least in terms of transportation)
- Significantly improve campus transport options for all stakeholders
- Encourage and educate our students, staff and faculty to 'go green' - because it works
- Get more people using healthy transport options
- Improve personal interaction by making it easy and fun to get out and about on campus
- To build a serious and world-class research programme in personal mobility

We aim to develop a personal mobility solution which is sustainable and viable for hundreds of daily users in the well-defined area of the NTU campus (plus cleantech park), showcasing the latest advances in mobile computing and electrical power assist technology.

Specifically, our aim is for (i) a fleet of 100 advanced[1] NTU-designed electric bicycles for our campus, (ii) 10 solar energy assisted bicycle charging stations located at convenient points around campus, (iii) a centralized web-based booking, authentication and monitoring system, (iv) an active culture of participation from student groups who will actually operate the system, (v) a significant impetus to advance NTU's research base in e-transportation.

Our team and support network

Associate Professor Ian McLoughlin	Earth Observatory of Singapore/School of Computer Engineering
Professor Wang Youyi	School of Electrical and Electronic Engineering
Associate Professor Ng Heong Wah	School of Mechanical and Aerospace Engineering
Assistant Professor Tan Su Lim	School of Computer Engineering
Professor Subodh Mhaisalkar	School of Materials Science and Engineering, ERI@N
Associate Professor Doug Maskell	School of Computer Engineering

JTC Cleantech park team	have offered to fund one charging station in the cleantech campus
Sanyo eneloop bike team	who we are signing an MOU with on eBike technology
LTA Vehicle Engineering Division	who are currently approving the first few prototype bikes for road use
NTU Cycling Club	NTU student club
Earthlink	NTU student club
GSTS	Green and Sustainable Technology Society, NTU student club
ERI@N	ERI@N are definitely supportive - they arranged the link with JTC

Selected technical details

More details follow later, but for the curious reader, here are a few of the technical details upfront.

The bikes are fairly standard road models equipped with small electric motors, and a very intelligent but tiny Android-based touch-screen handlebar computer. Users will need to pedal the bikes with a very light pressure, and the motor does the remaining work: no matter whether the rider is on the flat or riding up hill, their pedalling effort remains small. We plan to set the degree of effort equivalent to the energy expended by an average person when walking at a comfortable pace.

Lithium-Ion batteries and regenerative braking (using the motor to generate power when braking), are used to provide a range well in excess of anything required for campus travel! Batteries are recharged when the bikes are 'docked' to the charging station. Large solar panels will supply energy to the charging station, but a mains backup will deliver power when solar power is insufficient (at night?)

1 *By 'advanced' we mean that these modern frames, brushless motors and controllers are equipped with the latest Android touch-screen computer devices including GPS navigation, WiFi connectivity, and some very intelligent algorithms for controlling the speed and motor power on the machines: as described in more detail later.*

Riders can pre-book machines over the Internet. At the charging station, they just need to swipe their MATRIC cards and enter a pin to unlock one bicycle. The bikes remain in contact with the main computer at all times (over WiFi), and advise their location (GPS) to the same computer. If they are taken off campus, the main computer is notified, the motor locks, and an alarm sounds.

Objectives

The primary objective of this entire project is to develop a proof-of-concept, cost-effective personal mobility solution suitable for hundreds of daily campus users within the next 5 years, taking into account:

1 Lack of parking space on campus: to have minimum impact on campus infrastructure.
2 The hilly terrain of NTU: no more effort required than strolling down the street.
3 Energy efficiency: to utilise renewable resources wherever possible.
4 Convenience: no license required, easy to find, easy to use, and easy to park.
5 Safety: to ensure users' and third-party safety (we've already been talking to LTA about this).

The secondary objective is to advance the current research in personal e-mobility, to demonstrate NTUs expertise to the world, and thus to pursue a slightly esoteric research thread compared to more popular but hugely expensive electric vehicle research - all with a medium to long term deliverable.

Vision Statement

The vision for the primary objective is a light bicycle-style transport, using electrical power to overcome the effects of NTU's hilly terrain: the NTU **ebi** ("e-bicycle"). **ebi**'s will be locked in charging bays located at several convenient hubs. These hubs will, wherever possible, be equipped with solar panels to augment **ebi** charging, although on overcast days or at times of heavy traffic, grid-connected electrical power will have to be used.

Potential users can connect to a web page which shows the location of free **ebi**, and allows them to book (and maybe even pre-book) an **ebi** at a particular location, for a given time or journey. Once at the charging bay, a user will be able to swipe their NTU matric card (or visitor card) and enter a PIN to 'check out' one **ebi**.

The user will mount the **ebi** and can use the on-board touchscreen interface to program their destination, or they may prefer to travel freestyle, in which case their location will be continuously displayed on the user interface map.

No special training, no license and no complex safety gear apart from a mandatory helmet, will be required for **ebi** users. They will simply mount the **ebi**, point it in the direction they wish to go, and begin to pedal. The motor then starts to kick in and assist their transportation.

The intelligent system coded into the touchscreen computer fitted to each **ebi** will know where it is at all times, and it's current status (who is using it, state of charge, distance travelled this trip, and since last maintenance, location, speed, roll, pitch and yaw angle). This can provide a vast amount of information to operators/users.
ebi computers are fitted with GPS and accelerometers, as well as speed, cadence and tilt meters. A built in WiFi (or possibly GSM/GPRS modem) allow each **ebi** to be in periodic communication with a dual-redundant central control computer. This computer also feeds the web interface that allows others to track **ebi** positions.

This intelligence allows some of the following features:

- The controller will first warn the rider, and then the **ebi** motor will 'freeze' whenever the device leaves the boundary of campus – a very effective anti-theft lock.
- The controller limits the **ebi** top speed to 25km/h (as mandated by the LTA).
- The controller limits **ebi** speed at known accident blackspots or dangerous areas on campus.
- Similarly, **ebi** speed and motor power is reduced when they are ridden into pedestrian areas.
- The controller shuts off **ebi** motor power in the event of sudden deceleration, or fall.
- Speed and power can be limited for new riders, until they have ridden for a few hours cumulative time.
- The system will 'learn' about particular users – where they go, how much they deplete the battery and so on. This is useful for scheduling, and ensuring each users is allocated the most suitable **ebi** based upon the state of charge of available machines.

- A rider may wish to stop off at a particular place en route to their destination. The **ebi** controller can be put into 'lock' mode, holding the **ebi** immobile until the rider returns and enters their PIN on the touchscreen interface.
- Some users may wish to pedal more, some wish to pedal less. Advanced users should be able to program their preference into the system. Perhaps they begin with 90% motor assist, after a few weeks move to 80%, then 60% and so on. Finally, they may use the motor only on the steepest hills. The **ebi** controller will allow this – plus, like the best exercise bikes, give the rider an estimate of the number of calories (kJ) they have contributed to the travel, and how much the motor has contributed.
- A nice user interface provides information such as location, speed, duration of journey, battery charge remaining, distance remaining. Perhaps also the location of nearby **ebi**'s, and nearby charging stations.

A financial stake by the riders may also be a useful feature to consider. Not simply to help finance the purchase of more **ebi** for campus, but in an way to encourage a feeling of collective ownership, and stimulate greater use. We may wish to involve faculty from the business school - although we don't want to charge so much it detracts users! This, however, is something to be explored at a later stage – it is not part of the current technical proposal.

The secondary objective is to ramp up NTUs research effort in personal mobility transportation, and to turn NTU into a major player on the world stage. For this, we are already collaborating with TUM - and the beauty of this arrangement is that although we share research focus and technical innovation, TUM concentrate on cars, leaving NTU to concentrate on it's niche research area of 2-wheeled personal transport.

Financial and technical information

Total funded duration: 18 months *but with a 5 year lifetime - see below for detail*

Q	Tasks for objective 1	Outcomes
Q1	Project planning, scoping Prototyping, design, test and build Up-front purchasing and hiring, team formation Detailed planning with OFPM on charging station locations	Team formation Detailed operating plan Planning documents
Q2	Definition of optimal **ebi** designs, bulk purchase of spares and supplies Award contract for installation of charging stations Plan infrastructure back-end (centralised control) Train student groups in building **ebi**s Obtain LTA type approval for **ebi** options Inspection and testing procedures identified First two charging stations completed	Optimal **ebi** design 2 charging stations LTA type approval Demo working systems
Q3	Student groups begin DIY construction of **ebi**s Inspection of built **ebi**s and deployment of first 20 **ebi**s campus-wide Official opening of **ebi** system More charging stations	Mass usage begins
Q4 to Q6	Continue to roll out **ebi**s Operate and monitor system Gradually expand usage base More charging stations	We now have 100 **ebi** s on campus 10 charging stations Usage statistics
Q7	Report, hand off to self-sustaining operating committee Analyse system, usage statistics, and publish	A working personal mobility solution for the NTU campus

Note: Q8 to Q20 are not shown here. The system will be handed off to a committee of university management, student, staff and faculty representatives. They will operate the system, and expand it if necessary during Q8-Q20. They may choose to charge users a small amount... However what is handed off to them will be a viable and working hire scheme for electric bicycles augmented with our computational intelligence.

CURRENT STATUS (15 October 2010)

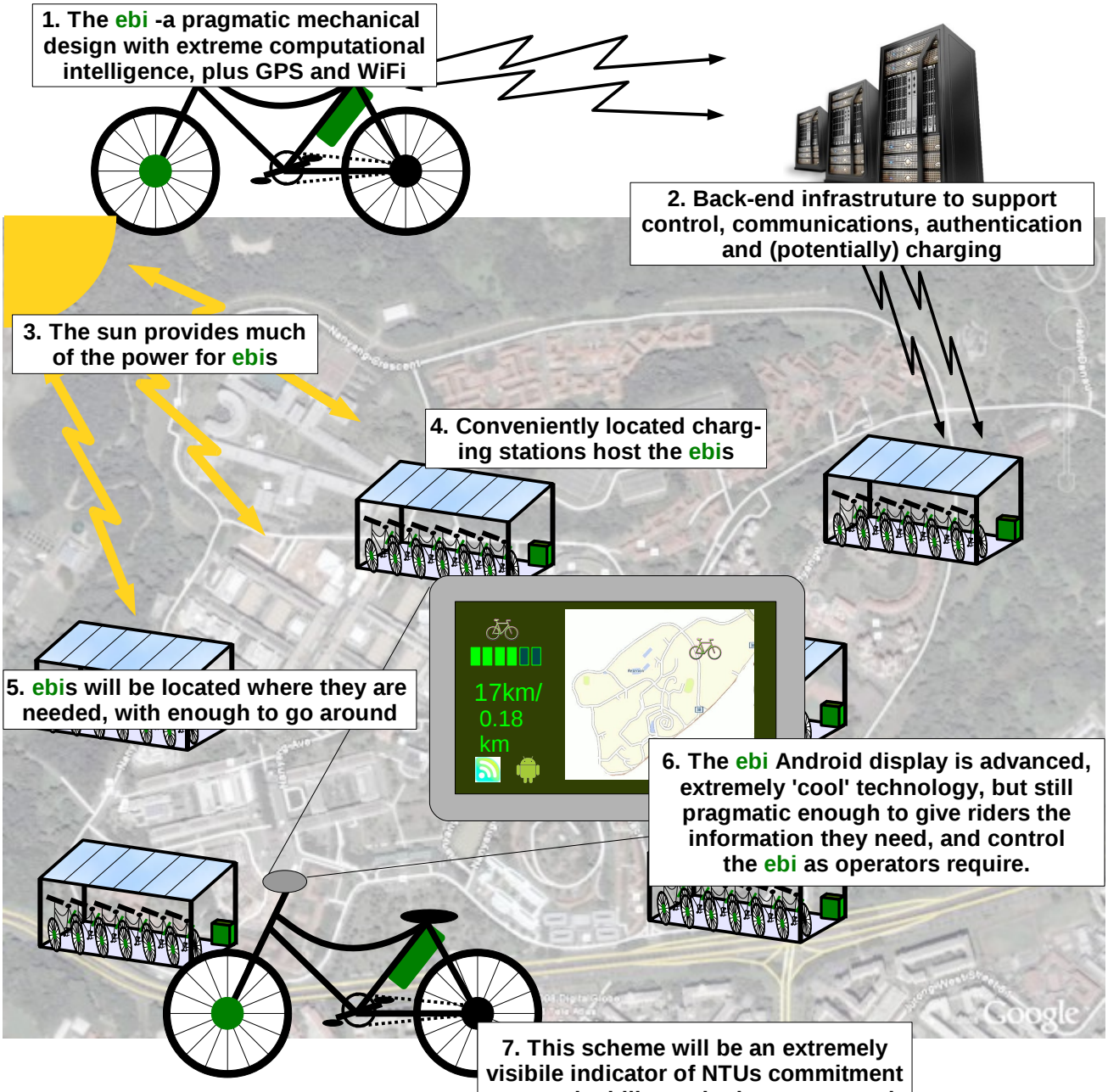
Building a fleet of 20 bikes of different types and capabilities as a research topic, before we start to choose a good one for NTU. Equipping each with a touchscreen Android computer.

Funding

Currently, approx. $15,000 one-off seed funding from ERI@N.
A request sent to NTU Provost for NTU 2015 funding - 100 bikes.

Request

For eBike schemes to be reflected in the NTU campus plan!



Background

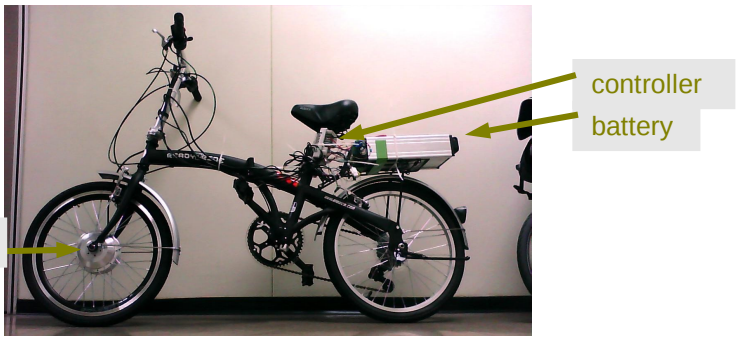
All of the members included in this proposal have been working in their own research areas that overlap with the **ebi** proposal (and are well recognised in their own right), however we will end with what is possibly the most relevant work. This is from Associate Professor Ian McLoughlin, who has been pursuing this with his undergraduate students since mid 2009 (without funding). Here are three examples from his work:

Prototype #1

standard bike frame
motor-assist for hills
conversion cost < S$1000
running cost < 1c/day
smart controller
LiFePO4 battery

Prototype #2

standard bike frame, smaller wheels
LTA-approved 250W geared motor
conversion cost ~ S$400
running cost ~ 1c/day
pedelec controller – no 'free ride'
rider assistance on hills
LiMn2O4 battery



Prototype #3

mechanical conversion currently in-progress
top of the range folding bike frame, smaller wheels
LTA-approved for taking on MRT/bus
has a much smaller/lighter battery (not shown)

Android computer