ADAPTIVE LIGHTING

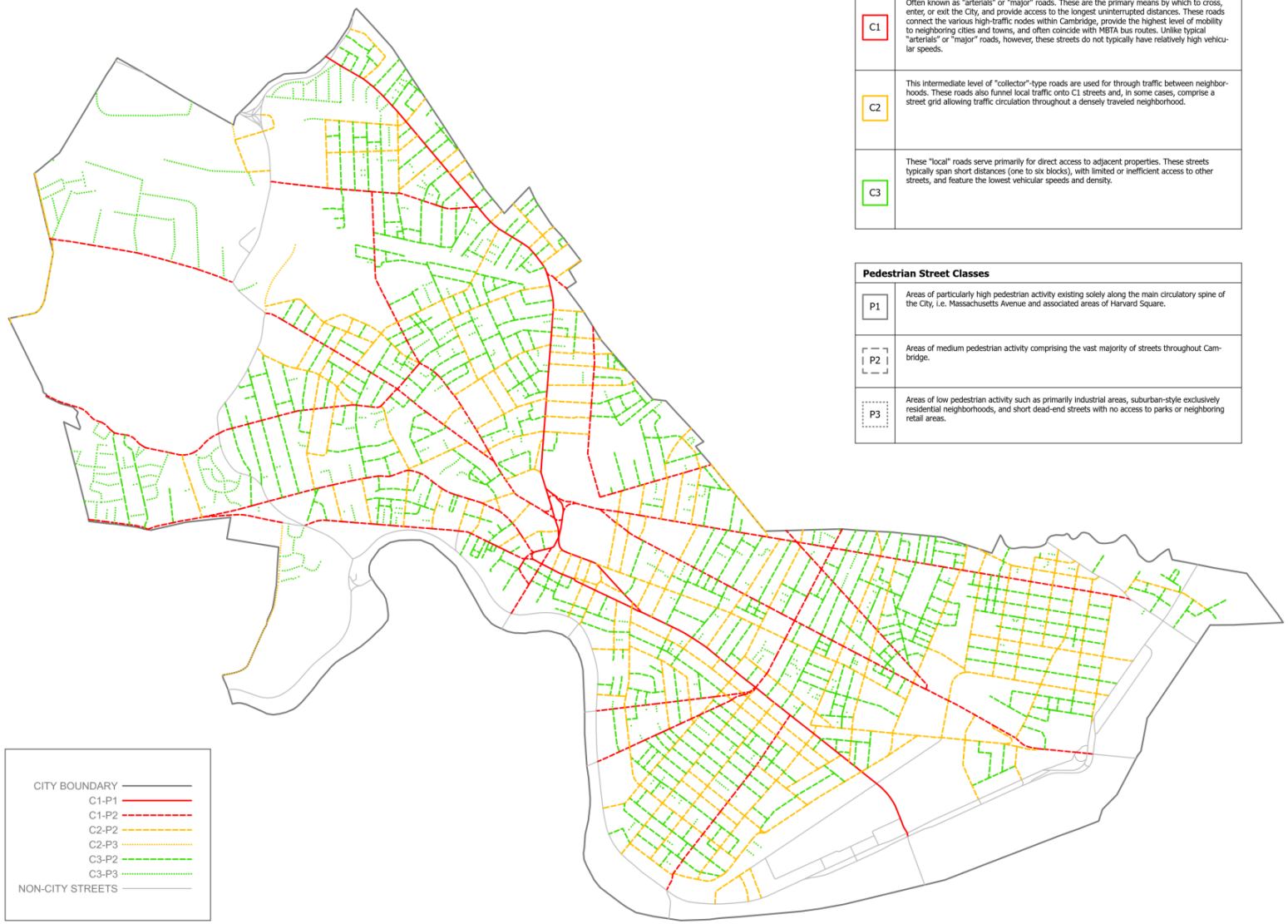
Lighting is for safety.

- Light levels determined by vehicle & pedestrian volumes
- Legacy light sources not able to be dimmed, vs. LED

Why use adaptive lighting controls?

- Save energy & operational cost
- Protect sleep health
- Prolong equipment life
- Maintain constant light output
- Connect with other systems, for a “Smart City”

ACEC-MA

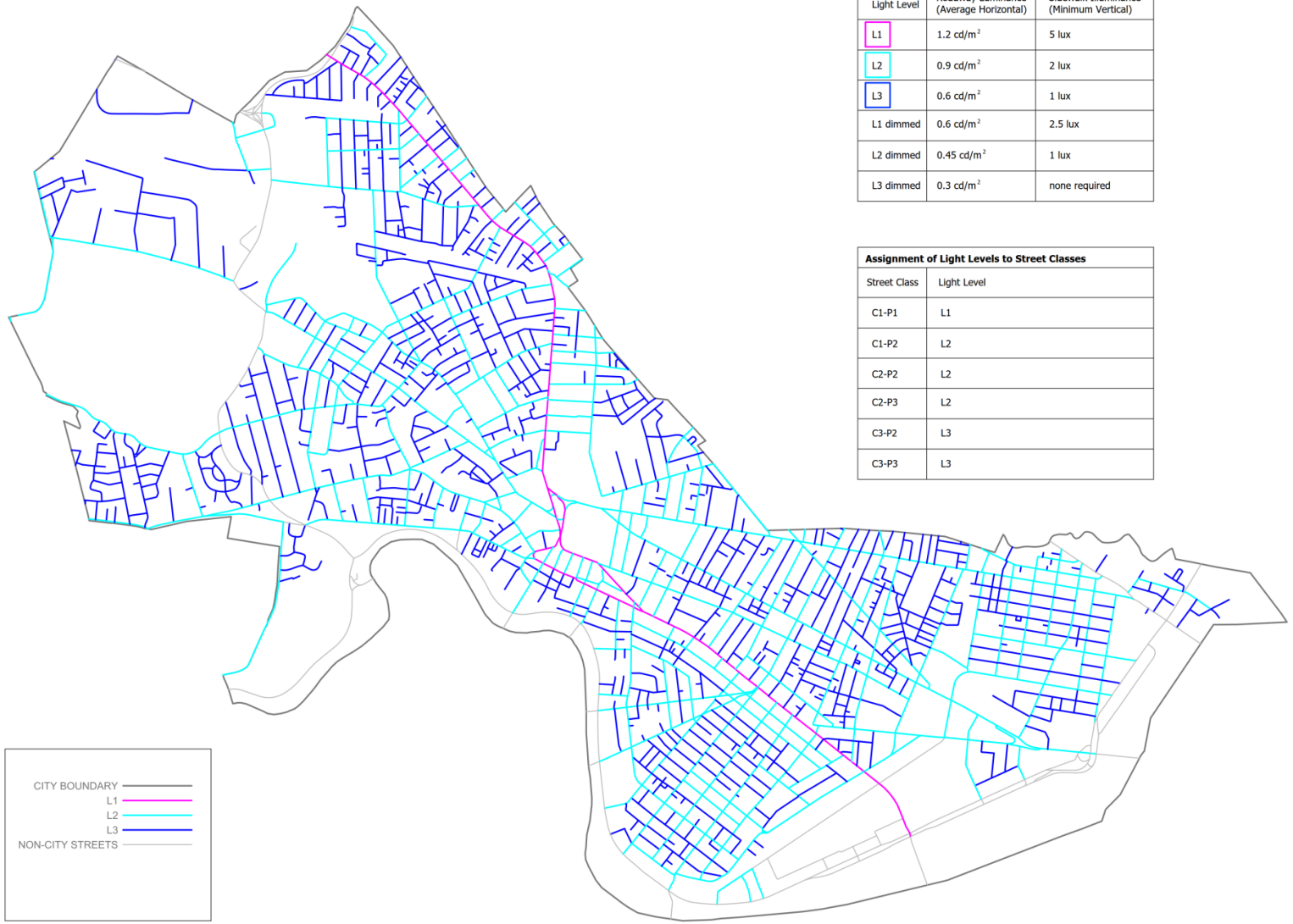


Vehicular Street Classes	
C1	Often known as "arterials" or "major" roads. These are the primary means by which to cross, enter, or exit the City, and provide access to the longest uninterrupted distances. These roads connect the various high-traffic nodes within Cambridge, provide the highest level of mobility to neighboring cities and towns, and often coincide with MBTA bus routes. Unlike typical "arterials" or "major" roads, however, these streets do not typically have relatively high vehicular speeds.
C2	This intermediate level of "collector"-type roads are used for through traffic between neighborhoods. These roads also funnel local traffic onto C1 streets and, in some cases, comprise a street grid allowing traffic circulation throughout a densely traveled neighborhood.
C3	These "local" roads serve primarily for direct access to adjacent properties. These streets typically span short distances (one to six blocks), with limited or inefficient access to other streets, and feature the lowest vehicular speeds and density.

Pedestrian Street Classes	
P1	Areas of particularly high pedestrian activity existing solely along the main circulatory spine of the City, i.e. Massachusetts Avenue and associated areas of Harvard Square.
P2	Areas of medium pedestrian activity comprising the vast majority of streets throughout Cambridge.
P3	Areas of low pedestrian activity such as primarily industrial areas, suburban-style exclusively residential neighborhoods, and short dead-end streets with no access to parks or neighboring retail areas.

Cambridge, MA

ACEC-MA



Light Level Criteria		
Light Level	Roadway Luminance (Average Horizontal)	Sidewalk Illuminance (Minimum Vertical)
L1	1.2 cd/m^2	5 lux
L2	0.9 cd/m^2	2 lux
L3	0.6 cd/m^2	1 lux
L1 dimmed	0.6 cd/m^2	2.5 lux
L2 dimmed	0.45 cd/m^2	1 lux
L3 dimmed	0.3 cd/m^2	none required

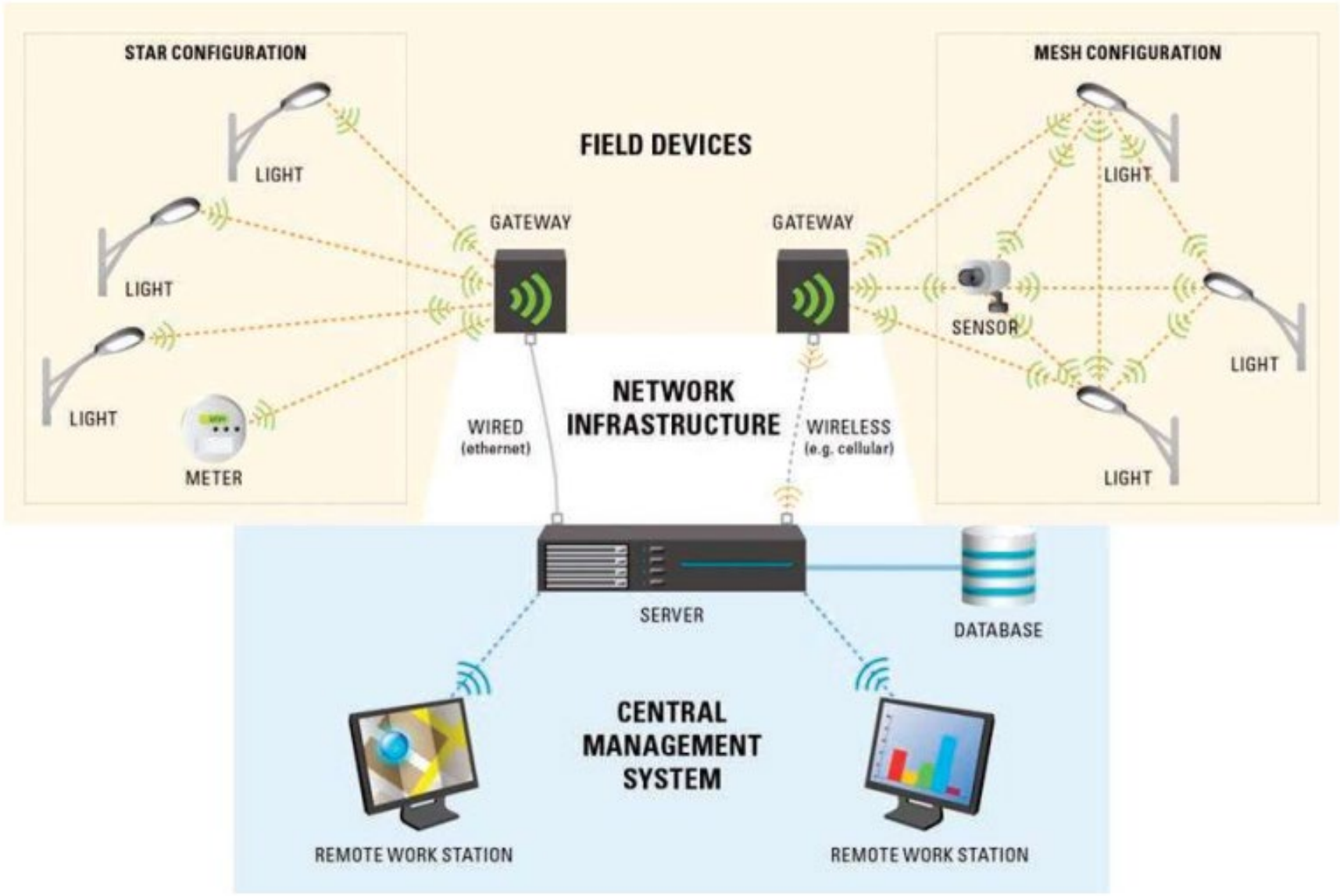
Assignment of Light Levels to Street Classes	
Street Class	Light Level
C1-P1	L1
C1-P2	L2
C2-P2	L2
C2-P3	L2
C3-P2	L3
C3-P3	L3

Cambridge, MA

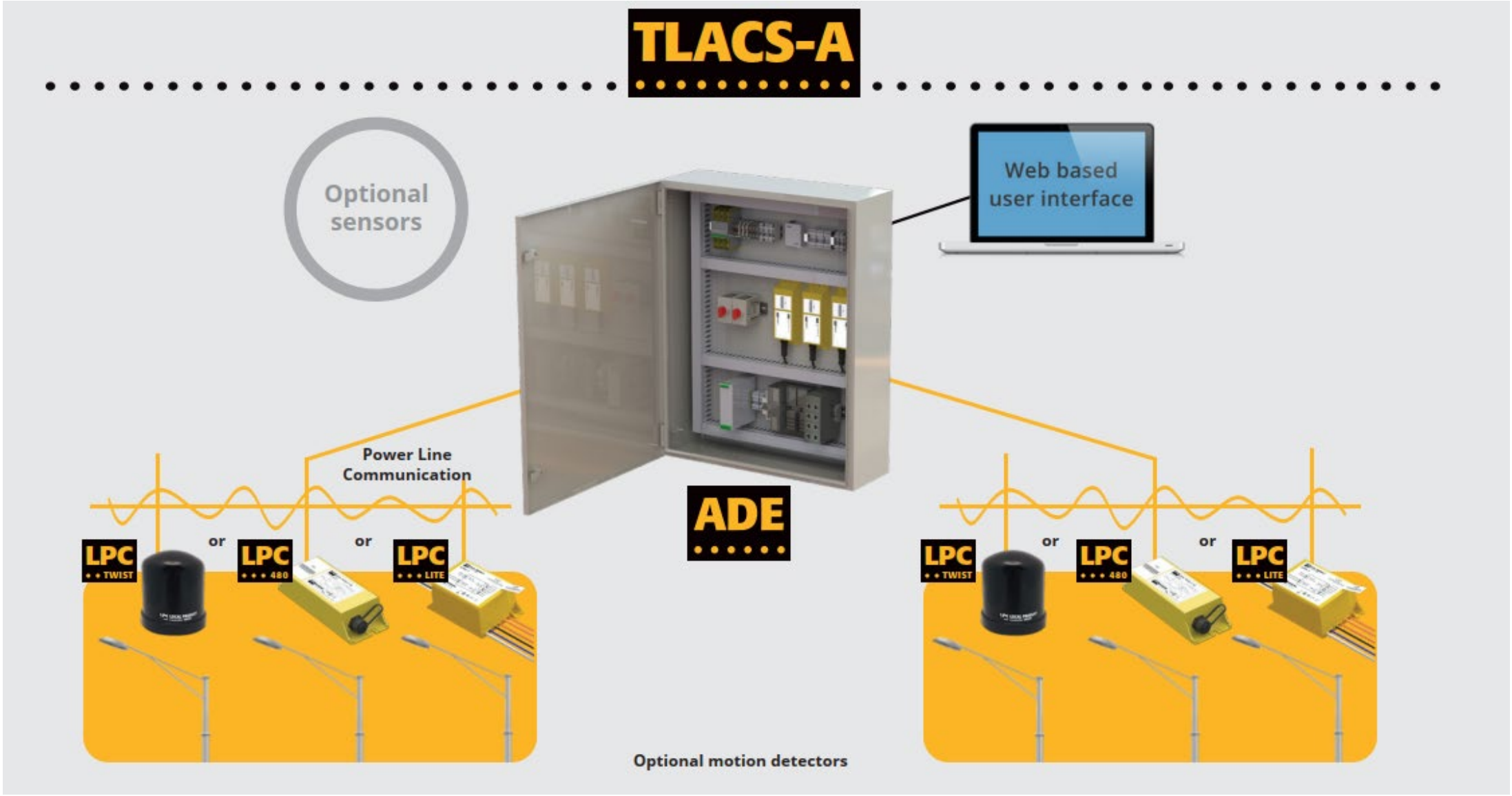
Lighting Design – Street Classification & Light Levels

Road and Pedestrian Conflict Area		Pavement Classification (Minimum Maintained Average Values)			Uniformity Ratio	Veiling Luminance Ratio
Road	Pedestrian Conflict Area	R1 lux/fc	R2 & R3 lux/fc	R4 lux/fc	E_{avg}/E_{min}	L_{vmax}/L_{avg}
Freeway Class A		6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Freeway Class B		4.0/0.4	6.0/0.6	5.0/0.5	3.0	0.3
Expressway	High	10.0/1.0	14.0/1.4	13.0/1.3	3.0	0.3
	Medium	8.0/0.8	12.0/1.2	10.0/1.0	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Major	High	12.0/1.2	17.0/1.7	15.0/1.5	3.0	0.3
	Medium	9.0/0.9	13.0/1.3	11.0/1.1	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Collector	High	8.0/0.8	12.0/1.2	10.0/1.0	4.0	0.4
	Medium	6.0/0.6	9.0/0.9	8.0/0.8	4.0	0.4
	Low	4.0/0.4	6.0/0.6	5.0/0.5	4.0	0.4
Local	High	6.0/0.6	9.0/0.9	8.0/0.8	6.0	0.4
	Medium	5.0/0.5	7.0/0.7	6.0/0.6	6.0	0.4
	Low	3.0/0.3	4.0/0.4	4.0/0.4	6.0	0.4

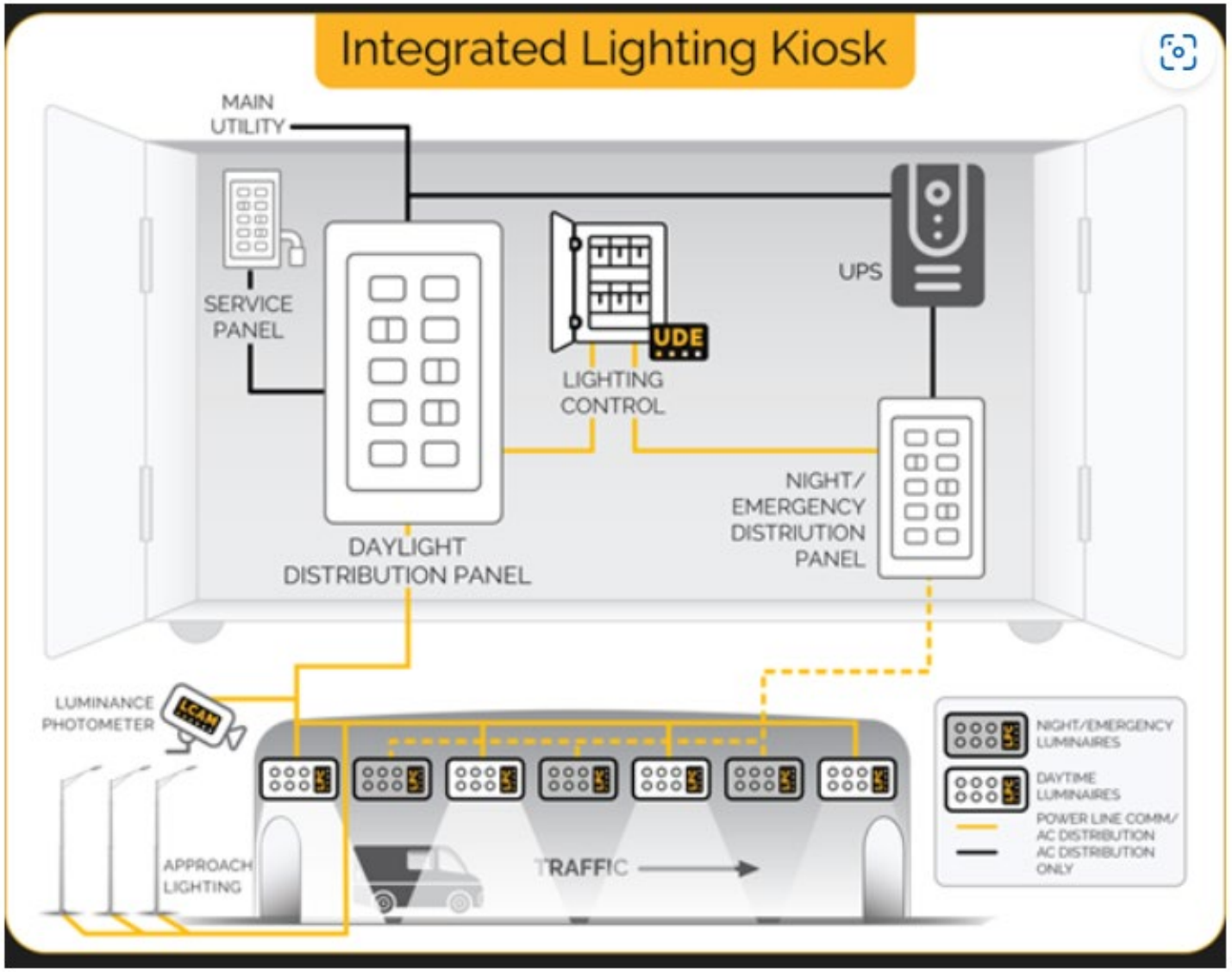
System Design – Networked Control System, Wireless



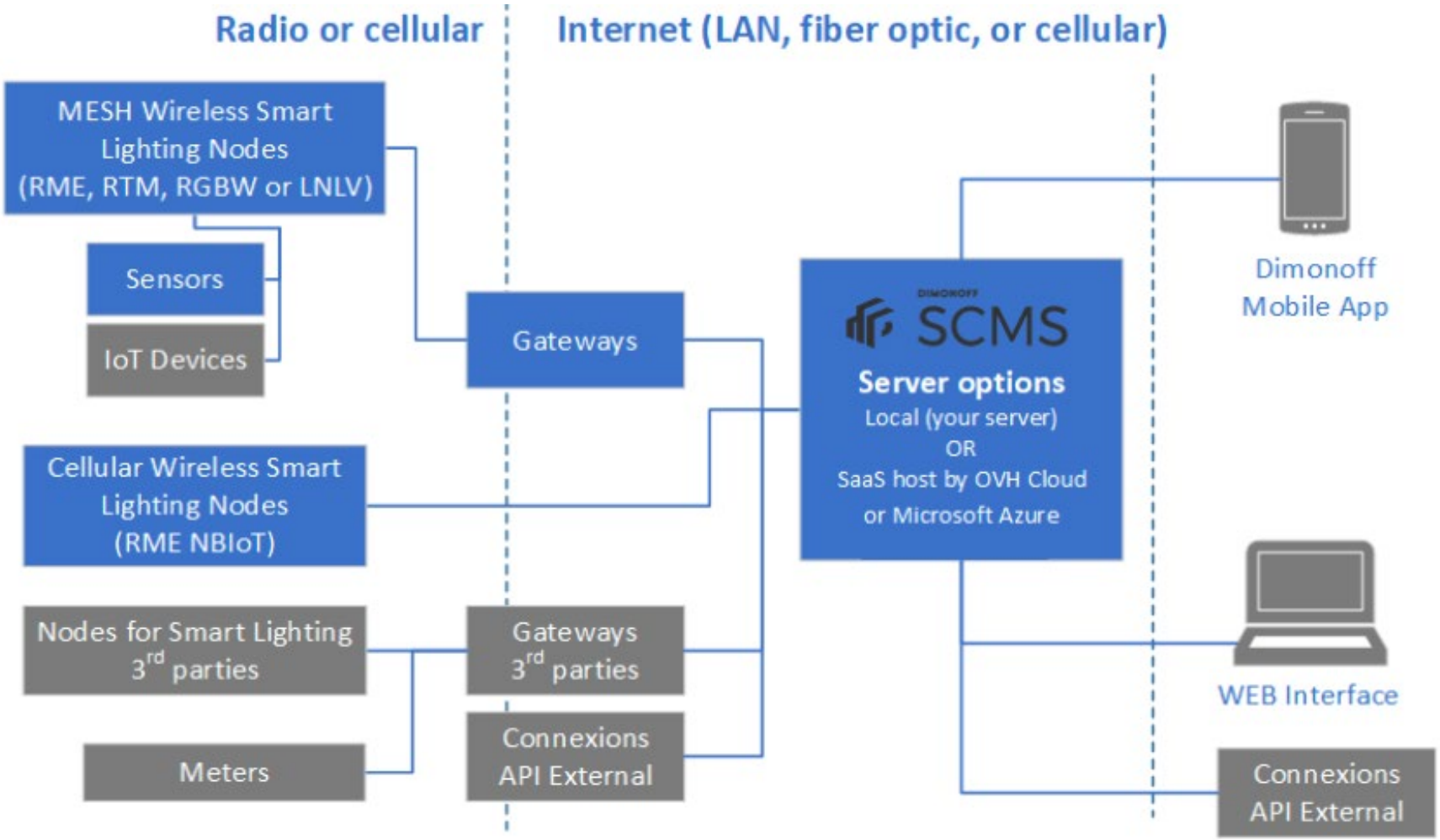
System Design – Networked Control System, Power Line Carrier



System Design – Power Line Carrier in a Tunnel

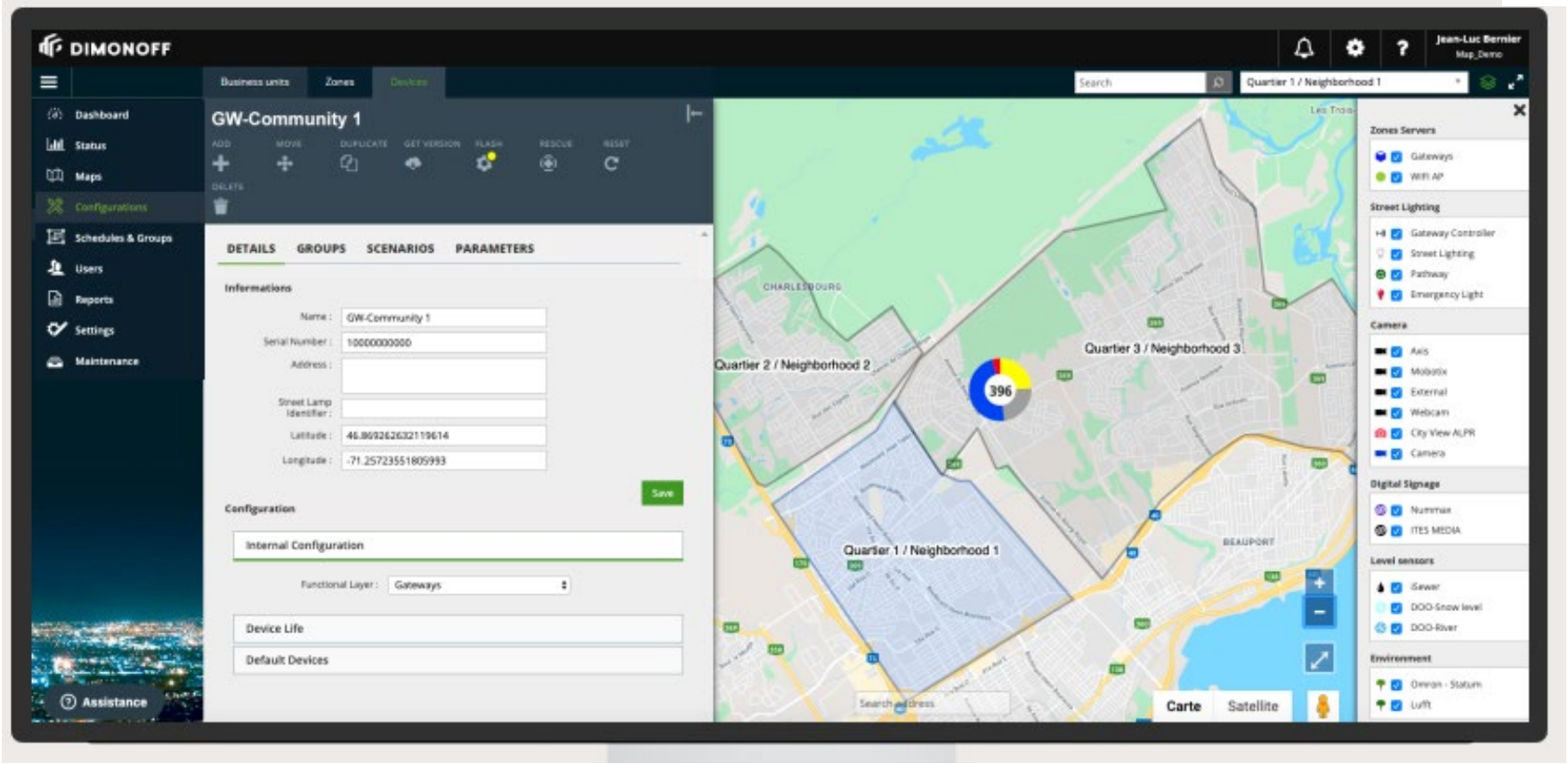


System Design – “Smart City” Controls



Example system diagram from Dimonoff. A Dimonoff system is currently in use in Cambridge, MA.

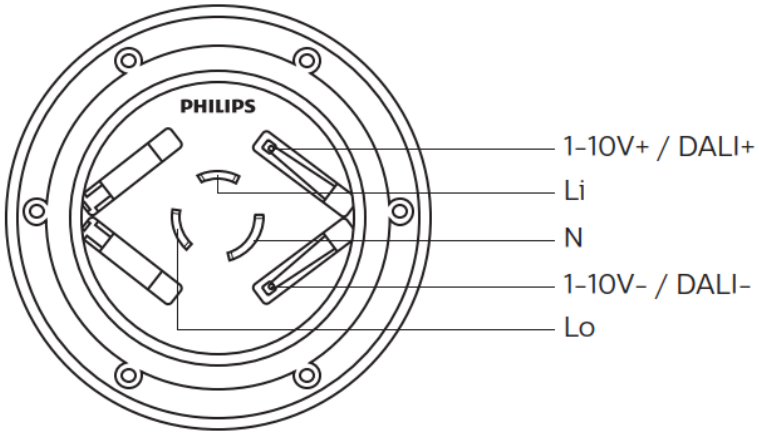
System Design – Components



Example Smart Central Management System screen, and gateway.

System Design – Components

Example control node and receptacle



Realization – dimming at curfew

Energy Saving

Dec		Duration at 35%	Sunrise	Day	Sunset	Duration at 70%	10PM Set-Back	Duration at 35%		
12/01/15	0:00	6:53	6:53	9:20	16:13	5:47	22:00	2:00	0:00	
12/02/15	0:00	6:54	6:54	9:18	16:12	5:48	22:00	2:00	0:00	
12/03/15	0:00	6:56	6:56	9:16	16:12	5:48	22:00	2:00	0:00	
12/04/15	0:00	6:57	6:57	9:15	16:12	5:48	22:00	2:00	0:00	
12/05/15	0:00	6:58	6:58	9:14	16:12	5:48	22:00	2:00	0:00	
12/06/15	0:00	6:59	6:59	9:13	16:12	5:48	22:00	2:00	0:00	
12/07/15	0:00	6:59	6:59	9:13	16:12	5:48	22:00	2:00	0:00	
12/08/15	0:00	7:00	7:00	9:12	16:12	5:48	22:00	2:00	0:00	
12/09/15	0:00	7:01	7:01	9:11	16:12	5:48	22:00	2:00	0:00	
12/10/15	0:00	7:02	7:02	9:10	16:12	5:48	22:00	2:00	0:00	
12/11/15	0:00	7:03	7:03	9:09	16:12	5:48	22:00	2:00	0:00	
12/12/15	0:00	7:04	7:04	9:08	16:12	5:48	22:00	2:00	0:00	
12/13/15	0:00	7:05	7:05	9:07	16:12	5:48	22:00	2:00	0:00	
12/14/15	0:00	7:05	7:05	9:07	16:12	5:48	22:00	2:00	0:00	
12/15/15	0:00	7:06	7:06	9:06	16:12	5:48	22:00	2:00	0:00	
12/16/15	0:00	7:07	7:07	9:06	16:13	5:47	22:00	2:00	0:00	
12/17/15	0:00	7:08	7:08	9:05	16:13	5:47	22:00	2:00	0:00	
12/18/15	0:00	7:08	7:08	9:05	16:13	5:47	22:00	2:00	0:00	
12/19/15	0:00	7:09	7:09	9:05	16:14	5:46	22:00	2:00	0:00	
12/20/15	0:00	7:09	7:09	9:05	16:14	5:46	22:00	2:00	0:00	
12/21/15	0:00	7:10	7:10	9:05	16:15	5:45	22:00	2:00	0:00	
12/22/15	0:00	7:10	7:10	9:05	16:15	5:45	22:00	2:00	0:00	
12/23/15	0:00	7:11	7:11	9:05	16:16	5:44	22:00	2:00	0:00	
12/24/15	0:00	7:11	7:11	9:05	16:16	5:44	22:00	2:00	0:00	
12/25/15	0:00	7:12	7:12	9:05	16:17	5:43	22:00	2:00	0:00	
12/26/15	0:00	7:12	7:12	9:05	16:17	5:43	22:00	2:00	0:00	
12/27/15	0:00	7:12	7:12	9:06	16:18	5:42	22:00	2:00	0:00	
12/28/15	0:00	7:13	7:13	9:06	16:19	5:41	22:00	2:00	0:00	
12/29/15	0:00	7:13	7:13	9:07	16:20	5:40	22:00	2:00	0:00	
12/30/15	0:00	7:13	7:13	9:07	16:20	5:40	22:00	2:00	0:00	
12/31/15	0:00	7:13	7:13	9:08	16:21	5:39	22:00	2:00	0:00	
		219:53:00				178:38:00		62:00:00		460:31:00
		2292:47:00				1278:48:00		730:00:00	**Yearly Total-**	4301:35:00
Hrs*Pwr%		974:25:59				1086:58:48		310:15:00		
Weighted Average of Hours * %Power										2371:39:47
%Average Power Used										55.13%

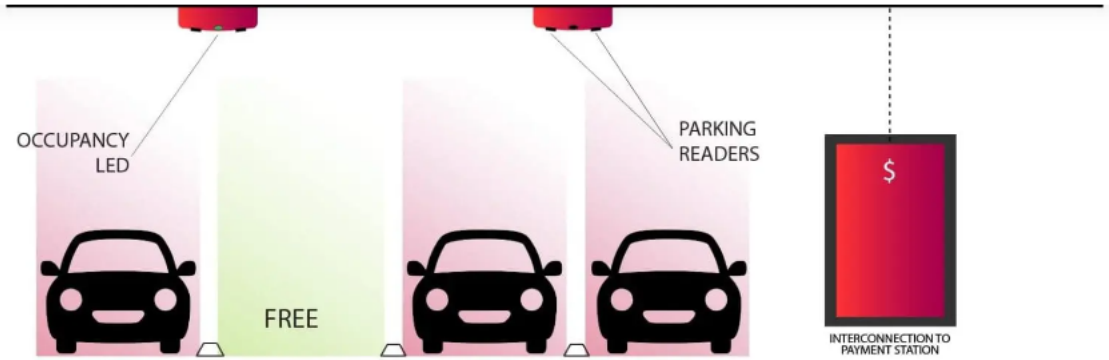
Additional “Smart” applications

DIMONOFF

LIGHTING MOBILITY SERVICES RESOURCES NEWS COMPANY

- Indicate occupied or available parking spaces to reduce search time in urban locations
- Perceive air quality, to ensure it meets city standards
- Distinguish sounds such as car accidents, gunshots or explosions, to support first responder operations and increase the safety of the population
- Recognize the presence of gas in the air to identify evacuation zones
- Optimize waste collection
- Know sewer levels in real time to avoid overflows
- Be aware of river levels in real time to warn citizens

Example “Smart” Application: Parking Management



INTERIOR

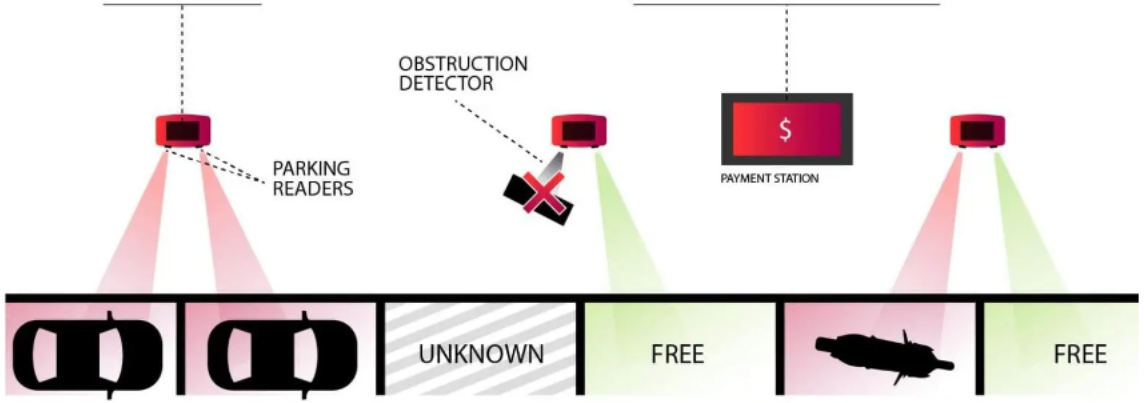
For multi-storey parking lots or other parking lots.

Can be installed on the ceiling (or also on the wall)

EXTERIOR

For curb-side parking or private outdoor parking lots.

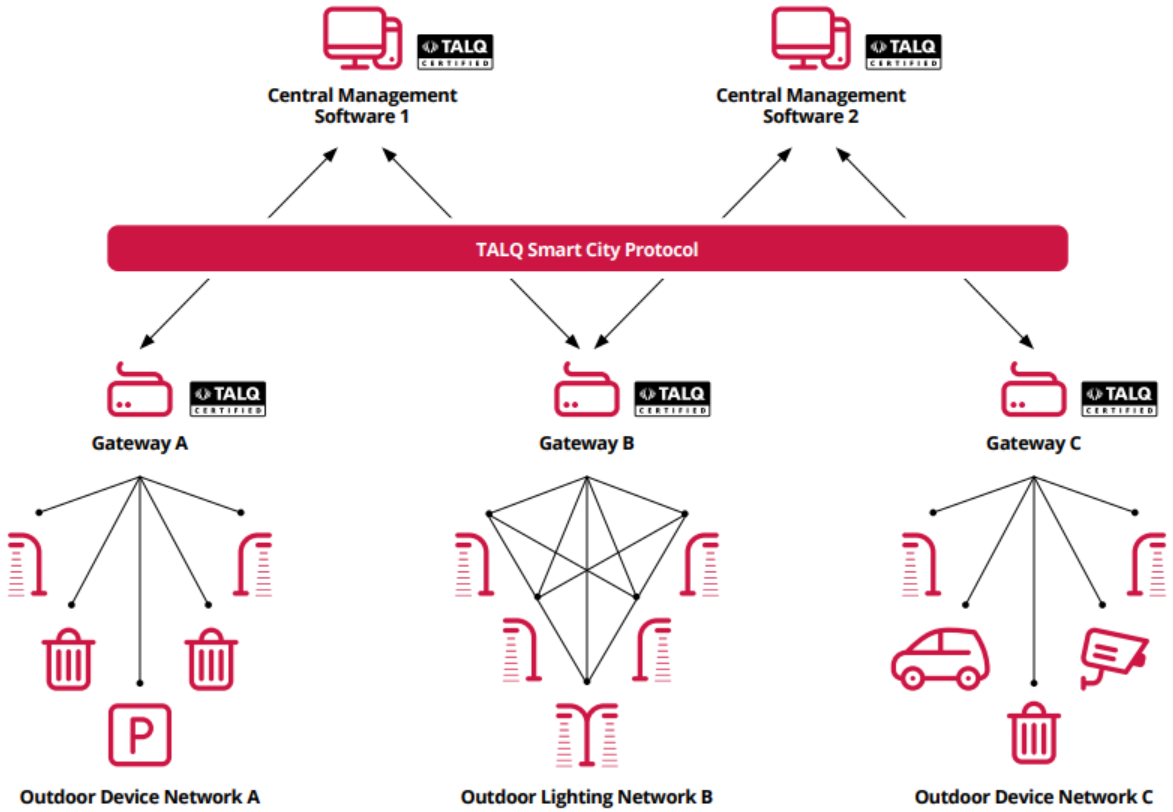
Installs in street furniture, such as parking bollards



Smart City Protocol

Intelligent control through the Smart City Protocol

The TALQ Specification defines a management interface for outdoor device networks, where one or more Central Management Software (CMS) solutions can control different device networks for various verticals in different parts of a city or region. It supports system monitoring and joint data collection, as well as simplified configuration and upgrades.



How did we do?

Why use adaptive lighting controls?

- **Save energy & operational cost – 45% or more**
- **Protect sleep health – dim lights after rush hour**
- **Prolong equipment life – minimize heat & current**
- **Maintain constant light output – adjust for system aging,**
  - **save money early**
- **Connect with other systems, for a “Smart City”**