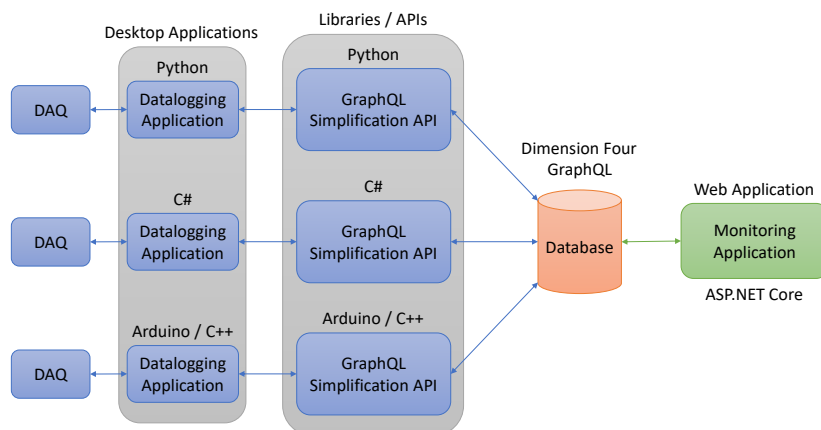


FMH606 Master's Thesis 2022
Industrial IT and Automation

Development of Open Source Datalogging and Monitoring Resources for IoT Platform



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Course: G[Ov[[-szQs yPCSS | [|

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External partner: *Dimension Four*

Summary:

dY ^^S^L>@CfObe\ C^z>- ^@e-qS Y@CeYb% C^z bH, dRs - ^@ - ..CAQeeYs- zSb^ @CSL^C@ zb S^zCq- < ..SP - K q-ePk X , dR yPC eqUC-z S -S C@ -z CfCq%b^C> zb q\ bfC zPC ^C@ Hbq K q-ePk X Wb..X@L>..PSC sS -V- ^Cb-sY%o Yb..S^L zPC ~sC bH? S C^sSb^ Gb-qS K q-ePk X sbY-zSb^i BteY ^-zSb^s HbqV%seCzs bHzPC <b^<Cez bH S^zCq^Cz bHzPS^Ls >zPCeY ^^S^L - ^@ @CfObe\ C^z bHzPC, dRs - ^@ ..CAQeeYs- zSb^>- ^@ zPC qS-VS^L eq@-<zi ? b<-\ C^z-zSb^ b^ Pb...zb S^sz-Y- ^@ ~sCzPC, dRs - ^@ ..CAQeeYs- zSb^i

Preface

K q ePk X \$ - l ~Cq%o^L--LC ..PS P \$ 4C b\ S'L GfCq \ bqC eqCsC^z S' zPC R^zCq^Cz bH
y PS^Lsi Gbq- ^ S^zCqCsZC@ @CfObeCq>4CL S^Cq bq CteCqz>zPCzS\ Cz b YC q^ - ^@ ~^@Cqz- ^@
K q ePk X \ - %^bz 4C -f- S' 4YD y P-s zPC eqbLz ..PS P \$ @b<- \ C^zC@S' zPS e-eCq...s
<qG-zC@ y PS e-eCq @b<- \ C^zs zPC @CfObe\ C^z bH, dRs - ^@ - ..CAQ eeYs- zSb^i y PC
, dRs -qC S' zPC Hbq\ bHYS4q qCs Hbq 4bzP d%zPb^ - ^@, q@-S'b>..PSC zPC..CAQ eeYs- zSb^
S @CfObeC@ S' , rdi^Cz ; bqC Hbq @z- \ b^SzbqS^Li y PC eqbLz <- \ C z b 4C 4C- -sC
zPC } ^SfCqS%bHr b-zPCB-szCq^] bq..%o.. ^zs z b s-eebqz Yb<-Y4-sS^Css>4%o-sS^L zPCsq
sCqfSd 3C<- -sC K q ePk X \$ ^bz - s-4UCz S' zPC <-qfS~Y\ > ^bq S zPCqC <-e- <S%zb
S^<Y-@C S>S ...s s-LLCszC@z b szqG \ YS^C zPC S^zCq zSb^ bHzPC sCqfSd..SfP , dRi y P-s>
zPS eqbLz ...s b^@-zC@- ^@<b\ eYzC@z b <Sj~\ fC^z zPC^C@HbqK q ePk X Wb..Y@LD
R^S S Yf%eY ^C@ Hbq sz-@^zs>zPS eqbLz S Hbq GfCq^b^C S^zCqCsZC@ S' -sS^L zPC sCqfSd
eqfS@C@4%? S C^sSb^ Gb-qj

? -S^L zPS eqbLz>..CP-fC..bqV@..SfP 4bzP zPC } ^SfCqS%o^@? S C^sSb^ Gb-qz-VB^L
s-LLCszSb^s Hbq\ 4bzPi R..b~Y@ YS^Cz b zP- ^W? S C^sSb^ Gb-qHbq-Yb..S^L \ Cz b <-qf%b-z
zPS eqbLz> ^@CseC-S Yf%zP- ^W? - ^SY,, -qPbY >HbqS Pb..S^L LqG-z S^zCqCsZ S' zPC eqbLz
-YzPC ...%Hbq\ sz-qz b " ^SfPi R..b~Y@ -Yb YS^Cz b zP- ^WzPC eqbLz s-eCqfSbq Hbq\
} r] >O- ^sC@CzCqO-YfbaC^>HbqL S^L s-LLCszSb^s>b^szq-<SfC <S S S\ >- ^@L-S@ ^<C
zPcb-LPb-z zPC eqbLz i dbqLq-^^>cDzP [-%f C|

Oí Vb^ OCLGSC^

Nomenclature

Symbol	Explanation
, dR	, eeYs- zS^ d pLq \ \ S'L R'zCqH <C
Rby	R'zCq^Cz bHy PS^Ls
, T, †	, s%<Pdp^b~s T-f-s<pe z, ^@† [X
} R	} sCq R'zCqH <C
} †	} sCq BteCqC^<C
K} R	K q-ePS<-Y} sCq R'zCqH <C
?, k	? -z- , < -SSzS^
} r]	} ^S'CoS%bHr b~zPB-szCq^] bq..-%o
[kyy	, ^ Rby <b\ \ ~^S<-zS^ edpzb<bY
K q-ePk X	, ^, dRI ~Cq%Y ^L--LC
d%zPb^	, ebe~Y q>PSLPY%qC @ 4YedpLq \ \ S'L Y ^L--LC
; `	, ebe~Y q>PSLP YfCYedpLq \ \ S'L Y ^L--LC
Ry	R^Hbq\ -zS^ yC<P^bVbL%o
} [X	} ^S C@[b@YS^L X- ^L--LC
, rdi^Cz	, ebe~Yq; ` Hq\ C.bqW
Oyyd	O%eCq Ctz yq ^sCq d pzb<bY

1 Introduction

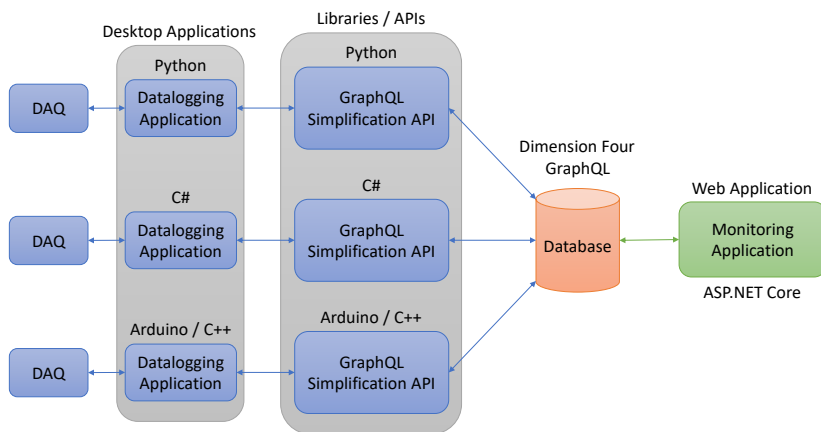
R^ zb@-%s ..bq\@bHR^@-szq%diCE- ^@S^zCq^Cz bHzPS^Ls> ^C... sbY-zSb^s Hbq @-z- QbYc<zSb^
- ^@ @-z-Q <<CssS4S6%o-qC 4CS^L @CfCbeC@ <b^sz- ^zY%o Gbq \ - ^%eCbeYc> Hbq C\ -\ eYc
Pb44%szs - ^@sz~@^zs>zS C \ -%4C- Pbz <b\ \ b@S%o ^@zP~sC CzSfCsbY-zSb^s 4C<b\ C
S^ - <<CssS4YD yPS epLc<z -S s zb S^<qC-sC - <<CssS4S6%zb s~<P - sbY-zSb^ 4%Cs- 4^SfS^L
, dR S^ sCfCq-Yebe~Yq epLq \ \ S^L Y^L--LCsi

1.1 Background

} r] -sCs @S Cq^z Rby eY-zHbq\ s zb@-%S^ ..SfPS^ zPC Ry - ^@, ~zb\ -zSb^ 3- <PCbq epQ
Lq \ - ^@zPC R^@-szqS YRy - ^@, ~zb\ -zSb^ [-szCq epLq \ >4bzP Hbq C@-<-zSb^-Y- ^@
qCSG-qP e-qebsCsi

? S C^sSb^ Gb-q fPzsesw@S C^sSb^Hb-qSg> - Yb<-Y <b\ e- ^%S^ K qC^Y ^@] bq..%P-s
@CfCbeC@- ^C...Rby eY-zHbq\ >..PS^P \ -%4C qCf- ^z zb -sC 4%} r] S^ zPC Hz-qD yPC
Rby eY-zHbq\ -sCs [kyy - ^@K q ePk Xi

yb -sCzPS eY-zHbq\ -z } r] >4bzP S^ C@-<-zSb^ - ^@qCSG-qP>, dR - ^@eq <zS- YC\ -\ eYc
^C@>zb 4C @CfCbeC@ Hbq @S Cq^z @CfS-Cs fd; s...SfP ?, k @CfS-Cs Hb\] -zSb^-YR^szq-Q
\ C^zs>, q@-S^b>- ^@p-se4Cq%al Sg- ^@epLq \ \ S^L eY-zHbq\ si yPC \ -S^ epLq \ \ S^L
C^fSp^\ C^zs - ^@epLq \ \ S^L Y^L--LCs-z } r] ..SfPS^ zPC 3- <PCbq\ -szCq epLq \ s
\ C^zSb^C@-4bfC-qC, S--Yrz-@Sow ` >d%zPb^>X-4, RB,, >- ^@[-zX, 3i



GS~qCic=

2 Internet of Things

R^zCq^Cz bHy PS^Ls \$s - <b^<Cez ..PS^P \$s -z zPC Hbq^p^z bHzPCR^@-szq%diCEqfby-zSb^i , z zPC <bqC \$z \$s -Y-4b-z S^Hbq\ -zSb^>..PCqC zPS^Ls CszPCq L-zPCq bq -<zs -eb^ b4z-S^C@ S^Hbq\ -zSb^i y PS^Ls \ -%@b 4bzP zPC L-zPCq^L -^@ -<zS^Li , zPS^L q^Cqz zb -^%o b4Lz ..PS^P <-^ L-zPCq bq -<z> -^@ \$s -4Y zb <b\ \ ~^S^-zC ..S^P bzPCq zPS^Ls q:i ; b\ \ ~^S^-zSb^ \$s bHzC^ @b^C bfCq zPC S^zCq^Cz> 4-z \ -%S^ sb\ C <-sCs <b\ \ ~^S^-zC zPcb-LP bzPCq @CfS-Cs fS 3Y-CzbbzP bq zPC Y^M

, ^ C^-\ eY bHR^zCq^Cz bHy PS^Ls \ -%4C - eCqsb^ -Y..G-zPCq sz-zSb^ ..S^P - \ b^Szbq^L ~^Si y PC sC^sbq \ -%4C <b^^C-zC@ zbLzPCq fS ,, RGR> -Yb..S^L %b- zb b4sCqfC zPC Yb<-Y..G-zPCq Hb\ zPC V^z-PC^ ..PSC 4qC.S^L <b^ C R^ -@Szb^ zb -e@-zS^L %b-q Yb<-Y \ b^Szbq^L ~^S^>zPC sC^sbq <b-Y@ <b\ \ ~^S^-zC ..G-zPCq zb - ..S^Cq ^Cz..bqW y PS^..b-Y@ -Y~sCq bHzPC s-\ C ^Cz..bqWzb b4sCqfC ..G-zPCq Hb\ %b-q ^Cz..bqW<b^^C-zC@ sC^sbq> -^@fS- fCq-i

r b\ Ceqps bHR^zCq^Cz bHy PS^Ls \$s zP-z \$z C^<b-q LCs @CfCbe\ C^z bHC <S^z -qPS^Cz-qC -^@sbHz..> qC@-Czb zPC\ S^S z-qC ^-z-qC bH@CfS^Csi y PCC <S^z ^-z-qC bHS- S@sbHz..> qC \ -%S^ z-q^ YC @zb - Yb..Cq 4-q Hbq C^zq%S^zb zS^Vzq^L -^@zC-P @CfCbe\ C^z>S^<qC-sS^L zC-POS^Cq <%oR^ -@Szb^ zb C <S^z sbHz..> qC>zPC <bYC-zSb^ bH@z- \ -%S^ z-q^ S^<qC-sC zPC -<<-q <%o ^@ C <S^<%bHS^@-szqS Yeq<CssCs> S^<qC-sS^L eqb@-zS^%o ^@ Yb..Cq^L <bszi Ob..CfCq\ -ss <bYC-zSb^ bH@z->CseC-S Y%ob^<Cq^S^L C^@Q-sCq>Ss -P-LCeqf- <%o <b^<Cq^i ? -z- \$s <bYC-zC@ CfCq%oPCq 4%GfCq%b^C> -^@zPS @z- \$s bHzC^ -4-sC@ ,, PSC R^zCq^Cz bHy PS^Ls \ -%4q^L HbqP G-s%zb -<<CszC-P @CfCbe\ C^z zbbYs -^@<b^<Cez>zPC f-sz -\ b~^z bHRoy @CfS-Cs \ -%obz C^<b-q LC eCbeYC ..S^Pb-z zC-POS^zCqCszs zb S^<qC-sC zPCq zC-POS^Cq <%oy PS^ \ -%@C-qC-sC bfCq YzC-POS^Cq <%o YbLzPCq

2.1 MQTT

[kyy \$s -^ a, rR sz-^@q@-^@P-sI ~S^W%4C<b\ CzPC @C^H <zb Rby <b\ \ ~^S^-zSb^s eqzb<bY Rz ..bqW^ b^ -sS eYCe~4YSPvs-4s<q^C\ b@C>..PCqCe~4YSPCq e~sP \ Csz-LCs zb - 4qWqj -^@s-4s<q^Cq qzqCfCs LCz s-S@ \ Csz-LCs Hb\ zPC 4qWqj ? -Czb zPC \ S^S z-qC ^-z-qC bHRoy > 4bzP se-<C> eqb<CszS^L eb..Cq -^@ 4-zCq%ob^s-\ ezSb^ ...s z-VL^ S^zb -<b~^z ..PC^ [kyy ...s @Csz^C@q:i

2.2 REST

pBry \$s bHzC^ \ \$s^zCqpczC@ -s - edpbz4-z \$s S^ H-z - ^ -q<P>S<C>z-q-Y sz%AC Hbq @CQ
fCibeS^L ..C4 sCqfS<S> - ^@, dRs q:i yPCpBry -q<P>S<C>z-qC \$s \ ebsC@bHL~S@CS^Cs Hbq
s%szC\ @CfCibe\ C^zsi yPCsCL~S@CS^Cs -qC @CSL^C@zb \ -fS\ S<C>s<-Y 4SS%> ^@\ b@SQ
"-4SS%>or bHz...qC - ^@, dRs @CfCibeC@ ~s^L pBry -q<P>S<C>z-qC -qC bHzC^ qCqpczC@zb -s
pBryHY q:i

2.3 GraphQL

Kq ePk X \$s - l -Cq%Y ^L--LC..PS<P> \ -VZs zPC <q> zSb^ bHfCqpsb^OCss, dRs ebssS4VQ Rz
..s @CfCibeC@4%zPC \ e- ^%Hbq\ Cq%W^b..^ -s G-<C4bbV^ ^b... [Cz->S^ |CE| i R^ |CEI >
Kq ePk X ..C^z beC^Cb~qC- ^@S\ -S^z-S^C@4%y PCK q ePk X Gb~^@ zSb^i Kq ePk X \$s
@CSL^C@zb \ -VZ, dR<q>C zSb^ G-s%o ^@YSLPz..CSLPz>..PCqC@CfS<S><- ^ qd ~Cz zPCseC^S <
@z- zPC%>^C@Hb\ zPC 4-<VZ^@ ? ~Czb Kq ePk X 4CS^L YSLPz..CSLPz>S \$s \ \ b^Y%o
~sC@S^ Rby sbY-zSb^s q:i

2.4 ASP.NET Core

, rdi] By ; bqC \$s - ^ beC^Cb~qC CtzC^Sb^ bHzPCi] By Hq \ C.bqW^Hbq @CfCibeS^L ..C4
-eeY<-zSb^si ; bqC-seC-zsbH, rdi] By -qCeCqHbq\ - ^<C- ^@<qbssC@Y-zHbq\ \ e-zS4SS%>
, s..SZP ; ` - ^@zPCi] By Hq \ C.bqW^, rdi] By ; bqC \$s @CfCibeC@ - ^@\ -S^z-S^C@4%o
[S<qpsbHz q:i

2.5 Thingspeak

yPS^LseG W<S>- eY-zHbq\ @CSL^C@-s- ^ Rby @z-Q^-Y%SS sbY-zSb^i yPCeY-zHbq\ -Yb..s
Hbq G-s%ofS--Ys-zSb^ bHYfC - ^@wbq -@ szbqC@ @z-i yb \ -VZ @z- - ^-Y%SS G-s%o
yPS^LseG W\ Cs ..SZP [-zX, 3 S^zCq zSb^>-Yb..S^L zPC -sCq zb e~Y @z- Hb\ zPC
yPS^LseG W-@zb [-zX, 3i yPS^LseG W<S>\ -@C- ^@\ -S^z-S^C@4%q -zP,, bqW^ R^<
zPC \ e- ^%4CPS^@[-zX, 3>-s- ^ G-s%sbY-zSb^ S^ - ^ CqCqLq..S^L Rby ..bq@q:i

2.6 Grafana

K q-H ^- S - ^ beC^Qb-q<C-ee\<S-zSb^>..PSP - S s zb ~^S%@-z- Htp\ S^@CeC^@C^z sb-q<Cs S' - ^ bq@Cq%HSpsb^i K q-H ^- <- ^ - <<Css @-z- Htp\ zPC -sCqs <PbSc bHszbq LC> 4C S - @-z-4- sC bq - sS^LYC 4b-q@ <b\ e-zCq> YS^C zPC p-se4Cq%dRi yPC -ee\<S-zSb^ ...s Y-^-<PC@S |CEJ>- ^@P-s 4CC^ S' <b^zS'-b-s @CfCbe\ C^z sS^<C Q.i

2.7 Github

K SP-4 S - <Yb-@Q- sC@ qCebSzbq%Hbq zq <V^L - ^@ \ - S'z-S'S'L sbHz..-qC <b@Q Rz -Yb..s @CfCbeCqs zb @CfCbe <b@C - Yb^LsSc bzPCq @CfCbeCqs>b^ zPC s- \ C eqpLz 2:i d qplCz s \ - %o Ysb 4Ce-4S>..PSP \ G ^s <b@C Ss fSS^YC Hbq Cq%b^C>bq eqf- zC>..PSP \ G ^s zPC <b@C Ss b^Y%fSS^YC Hbq sCz z S^@fS@-- Ysi K SP-4 LfCs @CfCbeCqs bfCqsLPz bfCq eqpLz <b@C - ^@fCqsSb^i , @CfCbeCq \ - %o PbbSczb HbqMoq 4q ^<P <b@C Htp\ - qCebSzbq%oy PS \ G ^s <qC-zS'L - @-e\<S-zC eqpLz>..PCqC <P- ^LCS \ - %4C @b^C ..SPb-z -' C-zS'L \ - S' eqpLz <b@Q ,, PC^ <P- ^LCS @bCzb zPC @-e\<S-zC Ss @b^C>S \ - %4C \ CqL@zblCzPCq..SP zPC bqfLS'-YqCebSzbq%oy PS eqp<Css zPC^ S'<Y-@C <P- ^LCS @b^C zb zPC @-e\<S-zC S' zPC bqfLS'-YqCebSzbq%o

2.8 IoT Maker Devices

R^zCq^Cz bHy PS^Ls Ss ^bz b^Y%o ^ S^@-szqS YqCfbY-zSb^>4-z P-s - Ysb eqp\ zC@zPC <qC-zSb^ bHsCfCq Y Pb44%sz zbbYsi y PCSc @CfS-Cs \ - %o^bz 4C @CSL^C@ Hbq S^@-szqS Y -sC - ^@ @-q 4SS%o 4-z zPC%o\ - VC Ct <CYC^z zbbYs Hbq qCsC qP - ^@ eqpzbz%eS^Li } sC@ S' zPS eqpLz Hbq zCzS'L e-qebScs -qC zPC \ SqpCb^zqPYCq 4b-q@> , q@-S'b >- ^@ zPC sS^LYC 4b-q@ <b\ e-zCq> p-se4Cq%dRi y PCSc 4b-q@S -Yb... sS^ eYC eqpLq \ \ S'L zb S'zCq <z ..SP eP%SS-Y P-q@...q> s-<P -s zC eCq z-qC sC^sbqS>- ^@ zb <b\ \ ~^S-zC ..SP bzPCq sbHz..-qC>- <qps ,, SSS- ^@ S'zCq^Czi

2.8.1 Arduino

, q@-S'b S - 4q ^@ bHs\ -Y sS^LYC 4b-q@ \ SqpCb^zqPYCq> @CSL^C@ 4%o <b\ e- ^%S^ Rz-Y%o..SP zPC s- \ C ^- \ Q y PC Lb-YbHzPC, q@-S'b <b\ e- ^%Ss zb C\ eb..Cq S^@fS@- Ys zb <qC-zC CQ-zq^S- Y%o^b^zqPYC@ <qC-zSb^s - ^@ Rby @CfS-Csi , q@-S'bs -qC @CSL^C@ zb 4CG-s%zb ~sC>S^CteC^sSfC - ^@ beC^Qb-q<C>4bzP S' P-q@..-qC - ^@ sbHz..-qC y PS -Yb..s ~sCqs zb eqpzbz%eC>zPC^ qC bfC ^b^QSSC^zS Y <b\ eb^C^zs Htp\ eqp@-zSb^ 4b-q@S QCE

2.8.2 Raspberry PI

y PCp - se4Cqf% dRS - sS'LYC 4b- q@ <b\ e~zCq> q-^^S'L - <~szb\ \ -@C>YLPz..CSLPz>@SzqfQ
4~zS^ bHXS~ti y PC <b\ e~zCq <b\ Cs ..SZP - K dRa >..PSP <- ^ 4C ~sC@zb S'zCqH <C...SZP
~sCq @CSL ^C@ CC-zcS- Y <Sj~Ss - ^@wbq sC^ sbqS 9c:i Rz <b\ Cs S' @S CqC^z sS Cs>..PCqCzPC
s\ -YCsZ Y <W- K } R - ^@ \ ~sz 4C - <<CssC@ zPqP~LP - ^bzPCq <b\ e~zCq y PC p - se4Cqf%
dR <b\ Cs ..SZP sCfCq YedpLq \ \ S'L Y ^L--LCs S'sz-YO@>zPC \ bsz ebe~Yq - ^@fCqS-zSC
bH..PSP - qCd%zPb^i y PC qCf-zSfC%o\ -YSSC - ^@ <b\ e~zS'L eb..Cq \ -VCS S - ebe~Yq
<PbSc - s - 4- sC Hbq Rby @CfS:Cs

3 Programming Languages

rGfCqYedpLq\ \ S'L Y ^L--LCs P-s 4CC^ - e-qz bHzPC @CfCbe\ C^z edp<Css Hbq zP\$ edpQ
UC-zi d%zPb^ - ^@; ` P-s 4CC^ -<zSfC%o-sC@ @-qS^L @CfCbe\ C^z> ..PSC K q ePk X \$
zPC <bqC bH? S\ C^sSb^ Gb~qs edp@-<zi y P\$ sC-zSb^ <b^z-S^s zPC qC sb^ Hbq <qC-zSb^ bH
zPCsC Y ^L--LCs>-s ..CY -s zPCsq -qC-s bH-sD „ PSC zC-P^S- YP% ^bz - Y ^L--LC> 4-z -
Hf\ C.bqW, r di] By ; bqC \$ @Cs<qS4C@S^ zP\$ sC-zSb^ -s ..CY

3.1 Python

d%zPb^ \$ - ^ C-s%zb YC-q^>P\$PQCfCYedpLq\ \ S'L Y ^L--LD R P-s sS\ eYC s%bz- † - ^@
C\ eP-sS C s <b@CqC @ 4S\$%oRz \$ - ^ S^zCqPzC@ Y ^L--LC> ..PSP \ G ^s S \$ zq ^sY-zC@
zb \ -<PS^C <b@C @-qS^L C^C<-zSb^i 3C<- -sC bHzP\$> zPCqC \$ ^b <b\ eS^zSb^ sz-LC>- ^@
4-L zCsS^L - ^@" †S^L \$ zPCqC HbqC G-sSq Q|:i d%zPb^ \$ beC^Gsb~qC- ^@zPCsb~qC <b@C
\$ \ -S^z-S^C@ 4%zPC d%zPb^ Gb~^@zSb^i ? -C zb zPC a r RQ eedpfC@ beC^Gsb~qC YS^C^SC
..PSP d%zPb^ \$ YS^C^sC@ ..SZP>S \$ HqC%o-s 4YC- ^@ @SzqS4-z-4YD y PC HqC @SzqS4-zSb^
C^zC^@s zb <b\ \ CqSY~sC Q{:i

3.2 C#

; ` \$ - ^ b4UC-zDqC^zC@> beC^Gsb~qC- ^@ <qbssC@Y-zHbq\ edpLq\ \ S'L Y ^L--LD ? ~C
zb S 4CS^L e-qz bHzPC; H\ S%bHedpLq\ \ S'L Y ^L--LCs>S \$ sS\ S^qzb ; >; j j >- ^@
T-f->zP-s C-s%zb eS^W~e S^H%o~ -YqC-@%Wb... b^C bHzPCsD R \$ C^LS^CqC@ zb <qC-zC
qb4-sz - ^@@-q 4YC- eeYs- zSb^s>HbqzPCi] By Hf\ C.bqW Rz ...s @CfCbeC@- ^@qCqC-sC@
4%q S qpsbH S | CEEE- Yb^L ..SZP zPCi] By Hf\ C.bqW QJ:i

4 Dimension Four

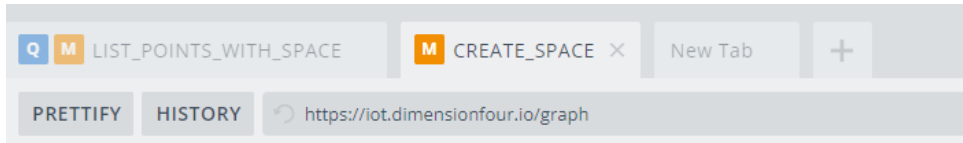
? S C^sS^ Gb~q, r S - zC-PQb\ e- ^%btp\ K qC^Y ^@>] bq..-%o- ^@...-s Csz- 4YSPC@ S^ | CEDi ? S C^sS^ Gb~qS-...- ^CC@ Hbq- @CfCbeCq HfC^@%o dR>..PSP q\ bfC@zPC <b\ Q eYcIz%bH..bqVSL ..SP - ^ Rby 4- <V@^@ y PCSq Lb-Y S zb @CfCbe - eY-zHbq\ -L^bszS- 4- <V@^@..PCq <b\ e- ^Ss - ^@zPCSq @CfCbeCq <- ^ <PbbsC zPC P-q@..:q zPC%o..- ^z bq ^CC@ R^ G-q%q Cfc>? S C^sS^ Gb~qY-~^<PC@zPCSq Rby eY-zHbq\ QI:i

4.1 GraphQL Solution

? S C^sS^ Gb~qS- zC-PQb\ e- ^%btp\ K qC^Y ^@>] bq..-%o- ^@S @CfCbeS^L - K q-ePk X , dR yPC -S bHzPC, dR S zb 4C 4bzP Hsz - ^@s<- Y 4Y> 4CS^L G-s%Hbq zPC Hb^zC^@ zb S^zCq <z ..SPi yPC, dR <b^sSzs bHqC-@%a -@C YCfCs bHbq\ - ^S -zS^ - ^@H^<zS^s Hbq S^sCqS^L>bq\ - ^S S^L>- ^@qzCfS^L @CSq@ @-z-i K q-ePk X <- ^ 4C S^zCq <zC@ ..SP zPq~LP Oy y d - ^@zP-s zPC? S C^sS^ Gb~q, dR S S^s Cq^z zb ..P-z @CfSC S sC^@S^L bq qzCfS^L S^Hbq\ -zS^>L^fC^ S eCqC^zs ~sCq LC^Cq zC@ <q@C^zS Ysi R^ - @zS^ zb zPC K q-ePk X, dR>? S C^sS^ Gb~q q^s - ^ [k y y 4qVWq y PC <q@C^zS Ys Hbq s- S@ 4qVWq <- ^ 4C q\ ~CszC@ Hb\ zPC, dR

4.1.1 Dimension Four Terminology

R^ zPCSq K q-ePk X r bY-zS^>? S C^sS^ Gb~qP-s Csz- 4YSPC@sCfCq YebS^zs bHbq\ - ^S -zS^i re-<C>dbS^zs>- ^@rS^ -Ys Hbq\ zPC szq-<z-qc bH..PSP @z- S sbqC@ re-<C>-<zs -s HbY@Cq> ..PSC ebS^zs - ^@sS^ -Ys qCeqC^zs @CfSCs - ^@ \ G-s-q\ C^zsi re-<C>-< ^ 4C ~sC@zb qCeqC^z - LC^Cq Y<bYc-zS^ bHbzPCqse- <C>bqebS^zs>Yb<-zS^>bqbzPCq Hc-z-qC ebS^zs \ -%P-fC S^ <b\ \ b^i, s- ^ C^-\ eYc>- PSCq q-P%bHse-<C>\ -%4C G- <zbc%CE Q dqb@-zS^ O-WCE Qdqb<Css Cfi r S^<CebS^zs qCeqC^z @CfSCs>zPC%o q^bz -Yb..C@zb P-fCs-4@bS^zi, ebS^z \ -%4C^-\ C@ y[d{v CE >S+ s%zC\ P-s b^Cbq\ bqCy[d{v zC eCq z-qC sC^sbqsi RH- ebS^z S -4Yc zb <bYc-z\ bqzP- ^ b^Cz%CbH\ G-s-q\ C^z>zPC z%Cb - ^@-^S S szbq@ ..SP zPC \ G-s-q@f-Y-C S^ - sS^ -Y, s ..SP ebS^zs>sS^ -Ys <- ^ ^bz P-fCs-4CS^ -Ysi RH- ebS^z w@CfSC S \ G-s-q^L sCfCq Y-^S z%Cs -z b^<C>zPC%o q zb 4C szbq@-s @Cq^z sS^ -Ys>- ^@CqzPCs \ CebS^zi B- <P se- <C>ebS^z>- ^@sS^ -YP-fC zPCSq b..^ R >..PSP <- ^ 4C ~sC@zb -<C>ss S^Hbq\ -zS^ -4b-z Si



GS~qCJic=y-4s Hbq bql- ^S^S^L I ~CqCsi

4.2 GraphQL Playground

? S C^Sb^ Gb~qs K q ePk X sCqfSC <- ^ 4C-<<CssC@ @SpzY%zPdp~LP - ..CAQdp..sCq , <Q <Css^L zPC} pX= Szi@S C^Sb^Hb~qjSbwLq eP >Vb-@s- ..CAQeeYs-zS^ zPC<b\ e- ^%P-fC ^-\ C@ dY%Ldp~^@i K fS^L - ^bfCqfSC...bHzPCeY%Ldp~^@>- ^@sz- qzS^L - z zPCzbe>zPCqC -qC S^@fS@--Yz-4s Hbq bql- ^S^S^L sCssb^s>S^ <- sCzPC ~sCq ^C@as zb -<<Css zPC, dR..SZP @S Cq^z zC^ ^zs - ^@vbq PG-@Cq>bq zb bql- ^S C zPCsqI ~CqCsi 3C^G-zP zPS>- 4-zzb^ Hbq eqCzS^S^L zPCI ~CqC>sPb..S^L P szbqf%b ~Cq%o ^@- } pXQI- q@SeY%S^L zPC<Y^z} pXi GS~qCJic @CeSzs zPCsC} RQCA C^zi

3C^G-zP zPS>zPC-eeYs-zS^ S seVz S^zb- YHQ- ^@qLPzP- ^@s@C yPCYHQ- ^@s@C S HbqI ~Cq%S^L zPC, dR..PSCzPCqLPzP- ^@s@C @SeY%zPC, dRqCseb^sD yPCYHQ- ^@> I ~Cq%S@C <b^z-S^s - YqLC" C@ ..SZP e-LS^zC@Y^Cs>-sC@ Hbq zPC -z--YI ~CqCsi yPS " C@ <- ^ <b^z-S^ \ -YSeYCI ~CqC>SH^C@C@ yPS " C@ S @CeSzC@4%" L-qCJi|i R^ zPC 4bzzb\ bHzPCYHQ- ^@s@C S z..b z-4s>I ~Cq%f-q 4YCs - ^@Oyy d PG-@Csi yPCI ~Cq% f-q 4YCs z-4 S ~sC@zb szbqf-q 4YCs HbqI ~Cq%S^L Y^V se-<CR? sbqebS^z R? si , -q 4YCs ..PSP -q bHzC^ ~sC@>4-z P-q@zb q\ C 4Cq yPC sC^b^@z-4>Oyy d PG-@Cq>S ~sC@zb sC^@ <qC^zS Y>Y^V zC^ ^z R? - ^@zC^ ^z V^%oy PS -q- S @CeSzC@4%" L-qCJici

R^ zPC \ S@C bHzPC ..CAQeeYs-zS^>4Cz..C^ zPCI ~Cq% C@ - ^@zPC qCseb^sC@SeY%o sSs- eY%4-zzb^ i yPS 4-zzb^ S ~sC@zb sC^@zPCI ~CqC S^ zPCI ~Cq% C@zb zPC, dR RHZPCqC -q \ -YSeYCI ~CqC S^ zPCI ~Cq% C@>- Ysz bHzPCI ~CqC -q sPb..^>- ^@zPC ~sCq S -sV@zb sC^z b^Q yPC sC^zC@I ~Cq% S zPC^ sC^z zb zPC, dR yPC " C@b^ zPC qLPzP- ^@sPb..s qCseb^sCs Hb\ zPCK q ePk X , dR..PC^ I ~CqC@ yPS " C@-Vb^L ..SZP - qCseb^sC S @CeSzC@4%" L-qCJiJi GS^Y%b^ zPCHqLPz C@LC bHzPC ..CAQeeYs-zS^> zPCqC -q z..b z-4s <b^z-S^S^L L~S@Cs - ^@zC eYzCs HbqI ~CqC>SHzPS S ^C@C@

```
1 mutation CREATE_SPACE {
2   space {
3     create(input: {name: "Production Hall 2" }) {
4       id
5       name
6     }
7   }
8 }
```

GraphQL query for creating a space.

```
QUERY VARIABLES  HTTP HEADERS (2)
1 { "x-tenant-id": " ", "x-tenant-key": " " }
```

GraphQL query variables and headers.

```
{
  "data": {
    "space": {
      "create": {
        "id": "6282675b7a4250b91ea4f0e0",
        "name": "Production Hall 2"
      }
    }
  }
}
```

GraphQL response showing the created space details.

5 Development

y PS <P-ezCq <b^<Cq's zPC eY ^^S'L - ^@ @CfObe\ C^z bHd%Pb^ - ^@ , q@-S'b Xs4q qQ
Ssw dRs> -s ..OY -s zPC \ b^SzbqS'L ..C4QeeYs- zSb^i Rz S @fS@C@ S'zb s-4QP-ezCqs>
sz- qS'L ..SIP Iic>zPC^ <b^zS^~S'L ..SIP zPC @CfObe\ C^z S' zPC bq@Cq zPC @S Cq^z eqbUC-z
e- qS ..Cq @CfObeC@ GSsz Ii|>zPC^ Ii{>C^@S'L b^ IiI

5.1 Planning

y PC @CfObe\ C^z bHzPS eqbUC-z P-s Lb^C zPqb-LP zPC eP-sCs bH} ^S @ eqb<Css>..PCq
G <P S^@fS@-Ye- qz S eY ^^C@ - ^@ @CfObeC@ S' Ss b..^ S'zCq zSb^i y PC S^<CezSb^ bHzPC
eqbUC-z <- \ CHp\ zPC} ^SfCqs%bHr b-zPC-szCq^] bq..%s @CsfCz b -sC Yb<- Y%@CfObeC@
Rby zbbYi Gqb\ zPS> sCfCq Y ~sCs ..Cq Cx 4bq zC@ ~eb^> s-<P -s ..PS-P eqbLq \ \ S'L
Y ^L--LCs ^C@C@- ^ G-s%o.- %zb -<Csz zPSz zbbY , s b^C bHzPC" qz szCes @-qS'L eY ^^S'L>
- s%szC sVz<P ...s @q ...^i GS -qCic @CeSzs zPCs%szC sVz<Pi yb VCe zq <WbHeY ^^C@
HC-z-qS bHzPC @S Cq^z Ys4q qCS> } [X <Y ss @S Lq \ s ..Cq z b 4C <qG-zC@ Hbq G <P Ys4q q%
} [X @S Lq \ s ..Cqb^Y%qG-zC@ Hbq zPCd%Pb^ Xs4q q% .PSCzPCqSz bHzPCeqbUC-z ..Cq
eY ^^C@ ~S'L - V - ^4- ^ 3b-q@ y PC HbYb..S'L eqbLq \ \ S'L Y ^L--LC sC-zSb^s -eeG-q S'
zPC bq@Cq zPC%o..Cq @CfObeC@ y b bq- ^S C <b@C> - K SzO-4 qebsz bq%o.-s Sz-4YSPC@
- ^@ S -f- S-4Y -z= Pzes-wLSP-4i <b\ wj r] CCLCs^vzH@eS ^@ b^Szbqi

5.2 Python Development

" PSC eY ^^S'L zPC d%Pb^ Ys4q q% sCfC^ H^<zSb^s ..Cq @q ...^ ~e S^ - } [X <Y ss @S Q
Lq \ i y PCsC ..Cq H^<zSb^s Hbq <qG-zS'L se- <Cs> ebS'zs> - ^@ sL^ - Ys> -s ..OY -s YszS'L
zPCsC> - ^@ - " ^- Yb^C Hbq qzqSfS'L zPC Y-zCs sL^ - YHb\ - seC-S <ebS'zi y PCsC sCfC^
H^<zSb^s ..Cq zPC^ - @C@ z b zPC \ - S' s-qez bHzPC Ys4q q%qG @%zb 4C @CfObeC@ B- <P
bHzPCsC H^<zSb^s <b^z-S' - szqS'L <- YC@ I ~Cq%o> ..PS-P <b^z-S's zPC K q ePk X I ~Cq%
Hbq zPC? S C^sSb^ Gb-q4- <V@^@> - ^@ - d%Pb^ @SzSb^- q%<- YC@ Lsb^ i y PS @SzSb^- q%
<b^sSzs bHzPC I ~Cq%o szqS'L - ^@ zPC f- qS 4YCs sC^z z b zPC H^<zSb^i

y PC " qz @CfObeC@ H^<zSb^ ...s <qG-zC se- <C > ..PS-P S ~sC@ z b <qG-zC se- <Cs S^ zPC
4- <V@^@ y b sC^@ zPC <qG-zC se- <C I ~Cq%zb ? S C^sSb^ Gb-q- ^ CSLPzP H^<zSb^ ...s

<qG-zC@ sC^@€ebsz S z-VC^ Hb\ zPC? S C^sb^ Gb-qsCf-\ eYD yPS H^<zSb^ qC<CfCs
zPC z-d.Cz @b\ -S^>Lsb^> - ^@ PG @Cps -s S'e-zs - ^@ sC^@s - qd -Csz zb zPC z-d.Czi R
...s sP-fC^ @b...^ zb eqfC^z S Hb\ eqS^zS^L zPC qC<CfC@ @-z- zb zPC zCq\ S'-Y> - ^@
qCz-q^s zPC @-z- zb zPC <-Y S^szG-@ ? ~qS^L zPC S^S^S^Y zCszS^L bHzPC <qG-zC€ se-<C
H^<zSb^>eCq\ Sssb^ @C^S^Y4C<- \ C- edp4Y\ i yPC zC^ - ^z zbVC^ ..PS-P ...s Csz-4YSPC@
Hbq @CfCbe\ C^z e-qpbsCs P-@ CfCq% @ S^S^zq zSfC eCq\ Sssb^>%z zPC 4- <VC^@ @C^SC@
zPC <qG-zSb^ bH- se-<d yPS ...s - ^ S^zCq^-Y Cppq-z ? S C^sb^ Gb-q..PS-P ...s " †C@S'
- \ -zzCq bH@% yPS ...s zPC b^Y% - UbqP-q@C@-qS^L zPC d%Pb^ Y4q q%@CfCbe\ C^zi
GSL-qC I ic @CeSzs zPC; qG-zCre-<C H^<zSb^>..PS-P -@PCqS zb zPC LC^Cq Yszq-<z-qC bH
-YI ~Cq%H^<zSb^>si yPCI ~Cq%szqS^L S @C^ ^C@>zPC^ <b\ 4S^C@ ..SP f-qS 4YCs zb <qG-zC
- l ~Cq%b4UC-z S^ zPC Lsb^ f-qS 4YD yPCI ~Cq%b4UC-z S zPC^ sC^z -Yb^L ..SP zPC
z-d.Cz - ^@ PG @Cps> zb zPC rC^@ dbz H^<zSb^> " L-qC I i{ i yPC z-d.Cz f-qS 4Y e-ssC@
zPcb-LP zPC H^<zSb^> S - szqS^L f-qS 4Y C d --Yzb zPC? S C^sb^ Gb-qeY%cp-^@} pX>
Pzes=wwfozi@S C^sb^Hb-qSbwLq-eP i yPC rC^@ dbz H^<zSb^> S^seS@ 4%? S C^sb^
Gb-qs Cf-\ eY C v:>sC^@s zPCI ~Cq%b4UC-z -s - ^ Oyyd qd -Csz zb zPC z-d.Cz>..SP zPC
PG @Cps <qC@^zS Y>- ^@ <PC^WHbq - ^%4- @qd -Cszs bq bzPCq edp4Y\ si RHzPCI ~Cq%..s
s-<<CsshY> S qCz-q^s zPCI ~Cq%b4UC-z


```

def send_post(target, json, headers):
    """Sends request to Dimension Four back-end.

    :param target: str
    :param json: dict
    :param headers: dict
    :return: dict
    """
    try:
        res = requests.post(target, json=json, headers=headers)
    except Exception as exception:
        print("Error!: " + exception)

    if res.status_code != 200:
        print("Send error!")
        print(res.text)

    else:
        res_json = res.json()
        if "errors" in res_json.keys():
            print("Query error!")
            print(res_json["errors"])
        else:
            print("Success!")
            return res_json["data"]

```

GS~qCl i{=rC^@sYL dbzs ..SP d%#Pb^i

? -q\$^L zPC @CfObel C^z - ^@ zCsz\$^L bHzPC S^SS YsCfC^ H^<z\$^>- ^S^zP H^<z\$^ Hbq
 <qG-z\$^L - PC @Cq @Sz\$^<-q%o..s <qG-zC@ zb <-z @b...^ b^ zPC ~sC bH@Sz\$^<-q\$si d%Q
 zPb^ @Sz\$^<-q\$ sP-qC- <b\ \ b^ szq-<z-qC...zP Ubb^i y PS\$ <qG-zC@ PC @Cq >" L-qC I J >
 H^<z\$^ z-VLs zPC zC^<-z R? szq\$^L - ^@ zPC zC^<-z zbVl^ szq\$^L - s S^e-zs>- ^@ qCz-q^s -
 PC @Cq @Sz\$^<-q%oy PC qCzCfC^ Y zCz€ sL^<-Y H^<z\$^< b^z-S^s - ^ - @Sz\$^<-Y 3bbY< ^>
 ..PSP \$ HYC 4%@CH -Yi y PS\$ H<z-qC \$ @CfObel@ zb -YzCq zPC qCz-q^C@ @-z-i , sL^<-Y
 qCz-q^ I ~Cq%hpb\ ? S C^s\$^ Gb-q \$ fCq%o-^..Sv@%o-s sPb..^ 4%L-qC Jij - ^@ \$ zP-s
 @CzCzY@ zb - Ysz <b^z-S^\$^L zPC @-z- f-Y-C- ^@ zS Csz-\ ei RHzPC H^YI ~Cq%\$ @CszC@>
 sS eY%z-q^ zPS 3bbY< ^ zq-C G\$-qC I i | @CeSzs zPC eqp<Csz bH@CzY\$^L zPC I ~Cq%o
 y PC " ^-YH^<z\$^ eY ^@C@- ^@ <qG-zC@...s zPC s-fC@ @-z- H^<z\$^i y PS\$ sS eY%z-VLs
 zPC @-z- - ^@ s-fC\$ S -s C\$PCq- i<sf bqilUbb^ " YI y PC " ^-YszCe bHzPC @CfObel C^z eqpQ
 <Csz \$ -eYb- @S^L zPC eqpU<z zb d^ dR ? b\$^L zPS -Yb..s Hbq zPC S^sz- Yf-z\$^ bHzPC Y\$4q q%o
 zPcb-LP zPC d%Pb^ e- <WLC\ - ^-LCq> eSe i [bsz L-S@Cs ..CqC sb\ C.P-z b-z@-zC@- ^@
 zPC sCz-ezbbYs ..C@-LC...s P-q@ zb qC-@ y PC bfCq Yeqp<Csz \$ ^bz zbb -@f- ^<C@ y PC
 " qsz szCe \$ zb eSe S^sz-Yf sCz-ezbbYs >..PSP \$ ~sC@..PSC <qG-z\$^L - sCz-eie%o" YC Hbq
 zPC eqpU<z i y PC sCz-eie%o<qfz \$ ~sC@ zb szq-<z-qC \ Cz-@-z- -4b-z zPC e- <WLC> Y\$V
 zPC ^- \ C >-zPbq - ^@ fCq\$^i y..b - @Sz\$^<-Y" YCs -qC qI ~\$q@ zb 4-S@ zPC e- <WLC=
 €€ S^z€€ie%o>..PSP <- ^ 4C\ eZ%o- ^@ e%eqpU<zizb\ Y>..PSP \$ ^C@C@ zb sCz-z zPC
 @CszC@ 4-S@ zbbY

y PC sC<b^@e- <WLC ^C@C@ zb 4CeSe S^sz-YC@ \$ 4-S@i , PC^ zPS \$ S^sz-YC@><P- ^LC
 @Sfz-bq%zb ..PCq zPC sCz-eie%o" YC \$ Yb<-zC@ y PC^ z%oC e%Q 4-S@ zb 4-S@ zPC
 e- <WLC , PC^ zPC 4-S@S^L \$ " ^SPC@-z.b - @Sz\$^<-Y" YCs -qC <qG-zC@=- iz-qL< - ^@-
 i..PYi y PC\$C" YCs -qC zPC b^Cs 4C\$^L -eYb- @C@ zb d^ dR y PS\$ \$ zPC " ^-YszCes bHLcz\$^L
 zPC e- <WLC -f- S^ 4Y b^ eSe i G\$sz> qLszCq - -sCq b^ d^ dR bqli y PS\$ ~sCq \$ ^C@C@
 ..PC^ -eYb- @S^L zPC e- <WLC] Ctz>eSe S^sz-Yf z..S^Ci y..S^C\$ ~sC@ zb -eYb- @zb d^ dR
 , PC^ S^ zPC s- \ C @Sfz-bq%o s sCz-eie%o Ctz-<zC z..S^C -eYb- @Sz\$^L S^ zPC zCq\ S^<-Y
 , PC^ qI ~CzC@> C^zCq %o-q d^ dR ~sCq^<- \ C - ^@ e-ss.bq@ Rhs~<<CszHY> zPC e- <WLC
 sPb-@ ^b... 4C S^sz-Yf 4C...zP eSe S^sz-Yf y PC? S C^s\$^ Gb-q, dR-qC ^b... S^sz-Yf 4C

```
def create_header(tenant_id, tenant_key):
    """Creates a Header for accessing the Dimension Four back-end.

    :param tenant_id: str
    :param tenant_key: str
    """
    headers = {
        "x-tenant-id": tenant_id,
        "x-tenant-key": tenant_key,
    }
    return headers
```

G\$-qC I J =y PC d%Pb^ ; qG-zC@C @Cq H^<z\$^i

```

def save_data(data, is_json=False):
    """Saves data in either CSV or Json format.

    :param data: list or dict
    :param is_json: bool
    :return: None
    """
    if is_json == True:
        with open('data.json', 'a', encoding='utf-8') as file:
            json.dump(data, file, ensure_ascii=False, indent=4)
    else:
        with open('data.csv', 'a', encoding = 'utf-8', newline='') as file:
            writer = csv.writer(file)
            writer.writerow(data)

```

GS~qClil =, H^<zSb^ Hbqs-fS'L @z-i

..SP eS S'sz-W@HeSi

5.3 Arduino Development

, szPC, q@-S'b S\$- eplq \ \ -4CsS'LYQ4b-q@\ ScpQb^zdpYQq..SZP fCq%bS S2O@\ C\ bq%o
zPC, q@-S'bXs4q q%oPb-Y@4CsPbqz - ^@<b^z-S' b^Y%oCC@O@H^<zSb^si a qL- ^S S'L I ~CqQ
SS>s~<P -s <qC-ZS'L ebS^zs bq se-<Cs>- ^@YSzS'L zPCsC>- qCYCs ~sO+YHbq- @CfS<C...PS<P
S \ bsZ%o-sC@ Hbq @z- L-zPCqS'L bq s%zC\ <b^zdpYS^Li Gq\ zPC eY-^^S'L eP-sC>zPqCC
<bqC H^<zSb^s ..CqC @C\ C@ ^C<Cs- q%o, H^<zSb^ Hbq qCzCfS'L sS^<-Ys>- H^<zSb^ Hbq
ebszS'L sS^<-Ys>- ^@H^<zSb^<Ys%zb I -Cq%zPC? S\ C^sSb^ Gb-qK q ePk X 4- <WQ^@

y PC " qsz @CfObel C^z S2Cq zSb^ <b^<Cq^C@zPC qCzCfS'L sS^<-Ys H^<zSb^i y PC H^<zSb^
sz-qC@-s- zCs bHzPC? S\ C^sSb^ Gb-qa eY Ct-\ eY Rz S- sS eY Ct-\ eY<>~S'L zPC
,, S; YC^z - ^@, q@-S'bOzze; YC^z Ys4q qCs zb sC^@Oyy d qI ~Czsi y PC " qsz P-q@C bH
z-q^S'L s- S@Ct-\ eYCS'zb- Ys4q q%h^<zSb^>...s-e-ssS'L zPCOyy d qY C^z - ^@r CqS YHb\
zPC \ -S' sWz<P zb zPC Ys4q q%o, s sCC^ S " L-qC I iv>qI Cq^<Cs Hbq- sCqS YszqC\ - ^@
Oyy d <YC^z S <qC-zC@~^@CqzPCeqf-zCsCzSb^i y PC^>zPCsC-qC e-ssC@zb zPC Ys4q q%oS'
zPC R^S r zqC\ H^<zSb^>@CeSzC@4%o L-qC I iui y PC sC-b^@ S2Cq zSb^ bHzPC @CfObel C^z
eP-sC <b^<Cq^C@zPC ebszS'L H^<zSb^i , s \ bsz bHzPC @S <-YsCs P-@4CC^ bfCq\b\ C S'
zPC " qsz S2Cq zSb^>zPC ebszS'L H^<zSb^ ..s \ -@C 4%o\ b@S'L zPC Ct-\ eY LfC^ 4%o
? S\ C^sSb^ Hb-q qv:><P- ^LS'L zPC K q ePk X I -Cq%o ^@- @S'L ^C<Cs- q%of- qS 4YCs zb zPC
qI ~Czsi GS~qC I iD @CeSzs zPC " qsz P-YHbHzPC qC @H^<zSb^>..PCq zPCI ~Cq%szqS'L - ^@
f- qS 4YCs-qC <b\ 4S^C@S'zb- I ~Cq%b4UC-zi GS~qC I i_ SY-szq zCs HqzPCq..PCq zPCI ~Cq%o
b4UC-z S sCqS YS C@- ^@sC^z zb? S\ C^sSb^ Gb-qj y PC, q@-S'b Xs4q q%o..s zCsC@b^ 4bzP
-^, q@-S'b [Vp cEE- ^@-^, q@-S'b } ^b ,, SSS Ob..CfCq..PC^ zCsC@..SZP sCfCq Y
qL-Yq, q@-S'b } ^bs ~sS'L -^ BzPCq^Cz sPSO@>zPC sWz<P @S^bz q^ edpeCq%o y PC
sWz<P ..b-Y@ <b\ eSC - ^@-eYb-@zb zPC @CfS<C>4-z zPC, q@-S'b ..b-Y@ HqC C-z q ^@b\
szCes S^ zPC sz-qz-e H^<zSb^i

```

6 #ifndef DimensionFourApi_h
7 #define DimensionFourApi_h
8
9 #include "Arduino.h"
10 #include "ArduinoJson.h"
11 #include "ArduinoHttpClient.h"
12
13 class DimensionFourApi{
14 private:
15     Stream * printer;
16     HttpClient * httpClient;
17 public:
18     DimensionFourApi();
19     void InitStream(Stream *print, HttpClient *client);
20     float ReadLatestSignal(const char* PointId, const char* TenantId, const char* TenantToken, const char* Server);
21     void PostSignal(float Signal, char* timestamp, const char* PointId, const char* TenantId, const char* TenantToken, const char* Server);
22 };
23
24 #endif

```

GS~qC I iv=y PC, q@-S'b Xs4q q%oC @Cq " YI

```

void DimensionFourApi::InitStream(Stream *print, HttpClient *client){
    printer = print;
    httpclient = client;
}

```

GS~qC|iu=d-sss'L ; YS^zs - ^@r Cq\$ Ys zb - ^ , q@-S'b XS4q q%o

```

float DimensionFourApi::ReadLatestSignal(const char* pointId, const char* tenantId, const char* tenantToken, const char* server){
    String query = R"("""
        query LATEST_SIGNALS(
            $pointId: String!
        ){
            signalsConnection(
                where: {pointId: {_EQ: $pointId}}
                paginate: {last:1}
            ){
                edges {
                    node {
                        id
                        timestamp
                        createdAt
                        type
                        unit
                        pointId
                        data {
                            numericValue
                            rawValue
                        }
                    }
                }
            }
        }
    )""";

    String postData;
    DynamicJsonDocument doc(2048);

    doc["query"] = query;

    JsonObject variables = doc.createNestedObject("variables");
    variables["pointId"] = pointId;
}

```

GS~qC|iD=Bsz-4YsPS'L zPCI ~Cq%b4UC-z S' zPC , q@-S'b XS4q q%o

```

serializeJson(doc, postData);
debugJson(doc, Serial);
debugln("Contacting Server");
httpClient->beginRequest();
httpClient->post("/graph");
httpClient->sendHeader(HTTP_HEADER_CONTENT_TYPE, "application/json");
httpClient->sendHeader(HTTP_HEADER_CONTENT_LENGTH, postData.length());
httpClient->sendHeader("x-tenant-id", tenantId);
httpClient->sendHeader("x-tenant-key", tenantToken);
httpClient->endRequest();
httpClient->print(postData);

int httpCode = httpClient->responseStatusCode();
debugln(httpCode);
if (httpCode > 0) {
    debug("[HTTPS] POST... code: ");
    debugln(httpCode);

    if (httpCode == 200) {
        String payload = httpClient->responseBody();
        debugln(payload);
        DynamicJsonDocument response(1024);
        deserializeJson(response, payload);
        auto signal = response["data"]["signalsConnection"]["edges"][0]["node"]["data"]["rawValue"].as<float>();
        return signal;
    } else {
        debugln("[HTTPS] POST... failed");
        String payload = httpClient->responseBody();
        debugln(payload);
    }
}
}

```

GS~qC|i_~rCqS YS'S'L - ^@ebszS'L zPCl ~Cq%b4UC-z zb ? S C'sSb^ Gb-q

5.4 C# Development

y PC, r di] By ..C4 -eeYs- zSb^ S zPC eqbUC-z s \ b^SzbqS'L sbh..-qD y PC \ -S' -seC-z bh
zPC..C4 -eeYs- zSb^ S zb @SeY%S'Hbq \ -zSb^ Hb \ ? S C'sSb^ Gb-q S' - ^ bq@Cq%hSPSb^>
zP~s qZqCfS'L l ~CqS -q @CC C@ \ bsz S ebqz- ^z @-qS'L eY ^^S'Li dY ^^C@ HC-z-qS
Hbq zPC -eeYs- zSb^ -q= qZqCfC se- <S - ^@ Ysz zPC \ >bq@Cq zPC se- <S - ^@ s-4Qe- <S
- <bq@S'LY%S' s- Se Ysz @SeY%S'Hbq \ -zSb^ -4b-z sS'LYC se- <S>s- <P -s ^- \ C>R? >s-4Q
se- <S - ^@ebs'z>@SeY%qZqCfC@S'L ^- Y Hb \ seC'S <ebS'z S' - Lq eP>@SeY%a ~VSeYC
Lq ePs> <q zC se- <C> <q zC>ebS'z> <q zC sL ^- Y

y PC" qsz S Cq zSb^ bhZPC, r di] By @CfCbe\ C^z eP- sC> b^ <Cq^C@ zPC qZqCf- Ybhse- <S>
-s...CY-s YszS'L zPCsC..SZP zPCsqebS'zsi y PCqC S ^bz - Ybz bhG sS%o <<CssS'YC S'Hbq \ -zSb^
b^ l ~Cq%S'L - K q ePk X 4- <VQ^@ Hb \ , r di] By >- ^@ - Ybz bhZPC S'Hbq \ -zSb^ b^ <Cq^s
zPC <q zSb^ bh- K q ePk X 4- <VQ^@ [bsz bhZPCsC ~sC K q ePk X YS4q qC S Hb \ zPC
] -K C z e- <WLC \ - ^- LCq , H Cq sb \ CqCq- qP>- sbY-zSb^>L S C^ 4% [- ~q d C z q S' Q u: >b^
^ b-y ~4Q , sS eYC l ~Cq%o-sS'L Oy y d qD ~Cszs - ^@] C. zb^sbh sCqS Y Cq y PC zC^ ^z
zbVQ^ - ^@VQ%o. CqC G sS%o @C@ z b zPC Oy y d <VQ^z S^ zPC sz- qz- e <Y ssi

y b \ -VQ s-q zPC b@C ..-s szq- z-q@ S' - ^ bq@Cq%hSPSb^> -Y b@C b^ <Cq^S'L zPC
l ~Cq%S'L bhZPC K q ePk X 4- <VQ^@ ..Cq eY <C@ S' zPC s- \ C <Y ssi , s l ~CqC S 4C- \ C
~sC+Y H ^ zSb^s Hbq sC^S'L zPCsC zb ? S C'sSb^ Gb-q ..Cq @CfCbeC@ b^ zPC lbi y b
bq- ^S C - ^@ szbqC zPC qCseb^sC S Hb \ ? S C'sSb^ Gb-q S' @S' S e- -Y <Y sS C S Hbq re- <S>

```

public class Space
{
    private readonly DFourConsumer _consumer;
    4 references
    public string id { get; set; }
    4 references
    public string name { get; set; }
    3 references
    public List<Point> points { get; set; }
    6 references
    public List<Space> subspaces { get; set; }
    3 references
    public Space(JToken json, DFourConsumer consumer)
    {
        _consumer = consumer;
        id = (string)json["id"];
        name = (string)json["name"];
        subspaces = new List<Space>();
        if (json["children"].HasValues) {
            foreach (var jSpace in json["children"]["edges"])
            {
                if (jSpace != null)
                {
                    var firstNode = jSpace.First;
                    if (firstNode != null)
                    {
                        var secondNode = firstNode.First;
                        if (secondNode != null)
                        {
                            Space space = _consumer.GetSpace((string)secondNode["id"]).Result;
                            subspaces.Add(space);
                        }
                    }
                }
            }
        }
    }
}

```

GS~qClicEYPCre-<C<Yss>S s epeCzSS> - ^@zPC " qz P-YHbHzPC S^sz- ^<S^L H^<zSb^i Rz eqe-qCs
 s-4Ge- <Cs>S^ <-sCzPCse- <C S - e-qC^zi

dbS^zs> - ^@rS^<Ys ..CqC Csz- 4YSPC@i y PCSc <YssCs - qC qCeqsC^zC@ 4%L~qCs licE licc>
 lic|> - ^@lic{i y PCSc b4UC-zs P- @f-qS 4YCs - ^@H^<zSb^s - @@C@ - s zPC H^<zSb^<Ys%bH
 zPC sbHz...qC S^<qC sC@i , s-^ Ct-\ eYC>se- <Cs ..CqC bqfLS^- Y%@CfObC@...SZP z..b szqS^Ls
 - ^@- Ysz bHebS^zs> 4-z -s H^<zSb^<Ys%LqC.>- Ysz Hbq s-4Ge- <Cs ..CqC - @@C@ zbbi

```
points = new List<Point>();
foreach (var jPoint in json["points"]["edges"])
{
    if (jPoint != null)
    {
        var firstNode = jPoint.First;
        if (firstNode != null)
        {
            var secondNode = firstNode.First;
            if (secondNode != null)
            {
                Point point = new Point(secondNode);
                points.Add(point);
            }
        }
    }
}
}
```

GS~qClicc=yPS "L-q @GeSzs zPC sC^@P-YhbHzPCre-<C <Y-ss S'sz-^<S'L H^<zS^i Rz eqe-qS zPC
Ysz bHebS'zs 4Cb^LS'L zb zPC se-<Q

```

public class Point
{
    2 references
    public string id { get; set; }
    2 references
    public string name { get; set; }
    4 references
    public List<string> types { get; set; }
    2 references
    public Point(JToken json)
    {
        id = (string)json["id"];
        name = (string)json["name"];
        types = new List<string>();
        var metadata = json["metadata"];
        if (metadata != null && metadata["types"] != null)
        {
            foreach(string signalType in metadata["types"])
            {
                types.Add(signalType);
            }
        }
    }
}

```

GS~qCl ic| =y PS\$ \$ zPC dbS'z <Y ssi

```

public class Signal
{
    1 reference
    public string id { get; set; }
    1 reference
    public string type { get; set; }
    1 reference
    public string unit { get; set; }
    1 reference
    public float value { get; set; }
    1 reference
    public DateTime timestamp { get; set; }
    1 reference
    public Signal(JToken json)
    {
        id = (string)json["id"];
        unit = (string)json["unit"];
        type = (string)json["type"];
        timestamp = (DateTime)json["timestamp"];
        value = (float)json["data"]["rawValue"];
    }
}

```

GS~qClic{=yPS @GeSzs zPCr S^~Y<Y-ssi

y PC " qsz p - < b q @ - LC zb 4C @ C f O b e C @ > .. C q z P C @ S e Y % H b q s e - < C s - ^ @ z P C s q e b S ^ z s i y P C
Y s z .. : s - ^ S \ - z C @ .. S P , T, t - ^ @ U f - s < q e z > s b .. P C ^ - s e - < C .. C q < Y S V O @ > z P C Y s z
.. b - Y @ @ S e Y % z P C s e - < C s e b S ^ z s i ; Y S V S ^ L - e b S ^ z .. b - Y @ q @ S q C - z z P C e - LC zb - @ S e Y %
H b q - e b S ^ z s s L ^ - Y i y P C " q s z S C q z S b ^ b H z P C s e - < C S O S z .. C q H ^ < z S b ^ - Y > 4 - z @ C \ C @
~ ^ b q . - ^ S C @ > - s S z @ S @ ^ b z b q @ C q s ~ 4 C e - < C s ~ ^ @ C q z P C s q q C s e C - z S f C e - q C ^ z s i

y P - s > - q C - q s s f C Y s z .. : s e d e b s C @ - ^ @ S \ e Y \ C ^ z C @ i , Y s z b H s e - < C s .. C q C - @ @ C @ z b
z P C r e - < C < Y s s > .. P S C z P C Y s z .. C q C < q C - z C @ .. S P p - < b q s % \ z - † b ^ z P C e - L D d b S ^ z s .. C q C
\ b f C @ b - z b H z P C Y s z > S ^ z b S z s C e - q z C @ S e Y % b ^ z P C q L P z C P - ^ @ s s @ C b H z P C e - L D ? b - 4 Y C Q
< Y S V S ^ L - s e - < C .. b - Y @ ^ b ... 4 q S ^ L z b z b z P C r S L ^ - Y @ S e Y % z b \ - V C z P C @ S e Y % b H s L ^ - Y S
H p \ q C Y - z C @ e b S ^ z s G s s C q

y P C d b S ^ z s O S z S - e @ z C @ ~ s S ^ L q d ~ C s z s z b z P C ; ` 4 - < V C ^ @ f S , T, t i y P C 4 - < V C ^ @
b H z P C e - L C S q C e q C s C ^ z C @ 4 % % L - q C l i c j > .. P S C " L - q C l i c l - ^ @ l i c v q C e q C s C ^ z s z P C O y [X
- ^ @ U f - s < q e z b H z P C H p ^ z C ^ @ i y P C H ^ < z S b ^ S ^ " L - q C l i c v ~ s C s - ^ , T, t q d ~ C s z z b
q d ~ C s z z P C e b S ^ z s 4 C b ^ L S ^ L z b e - q S ~ Y q s e - < d a ^ - s ~ < C s s H Y q d ~ C s z > z P C e b S ^ z s - q C
s b q C @ - Y e P - 4 C z S - Y % % ^ @ s z b q C @ S ^ - O y [X Y s z i


```

public class SpacesListModel : PageModel
{
    private readonly DFourConsumer _consumer;
    public Space space;
    public List<Space> spaces = new List<Space>();
    0 references
    public SpacesListModel(DFourConsumer consumer)
    {
        _consumer = consumer;
    }
    0 references
    public void OnGet()
    {
        PrepSpaces();
    }
    1 reference
    public List<Space> PrepSpaces()
    {
        _consumer.EstablishCredentials();
        spaces = _consumer.GetTopLevelSpaces().Result;
        return spaces;
    }
    0 references
    public JsonResult OnGetSpace(string id)
    {
        _consumer.EstablishCredentials();
        space = _consumer.GetSpace(id).Result;
        return new JsonResult(space);
    }
}

```

GS~qCl icJ=y PS\$ \$zPCre- <CX\$z 4- <V@^@

{{

```

<html>
<head>
  <script src="https://ajax.googleapis.com/ajax/libs/jquery/3.6.0/jquery.min.js"></script>
</head>
<body>
  <h1>Spaces and Points</h1>
  <div class="row">
    <div class="column">
      <h3>Spaces</h3>
      <div style="border: 1px solid black; padding: 5px; margin: 5px 0;">
        <code>foreach (var item in Model.spaces)
        {
          SubList(item);
        }
      </div>
    </div>
    <div class="column">
      <h3>Points</h3>
      <ul class="points_list" id="points_list">
      </ul>
    </div>
  </div>
</body>
</html>
<script>
$(document).ready(function () {
  $('tr.space_row').nextUntil('tr.space_row').slideToggle(10);
  $('tr.space_row').click(function () {
    var spaceId = $(event.target).attr('id');
    fillPointsLists(spaceId);
    $(this).nextUntil('tr.space_row').slideToggle(400);
  });
  $('tr.space_row').dblclick(function (event) {
    var id = $(event.target).attr('id');
    redirectPage(id);
  });
});
function redirectPage(id) {
  var base_url = window.location.origin;
  var path = "/SignalDisplay?id=" + id;
  window.location.href = base_url + path;
}
}

```

GS~qC lcl =y PS @eSzs zPC Oy [X - ^@Uf-s<e z 4PS^@zPCre-<CXsz p-<bc@-LQ

```

function fillPointsLists(id) {
  if (id != null) {
    $.ajax({
      type: 'GET',
      dataType: 'json',
      contentType: 'application/json',
      data: {
        id: id
      },
      url: '/SpacesDisplay?handler=Space',
      success: function (result) {
        var space = result;
        var points = space.points;
        var pointsList = document.getElementById("points_list");
        var first = pointsList.firstChild;
        while (first) {
          first.remove();
          first = pointsList.firstChild;
        }
        for (var i = 0; i < points.length; i++) {
          var point = points[i];
          var li = document.createElement("li");
          li.value = point.id;
          li.innerHTML = point.name;
          pointsList.appendChild(li);
        }
        var options = $("#nameList option");
        options.detach().sort(function (a, b) {
          var at = $(a).text();
          var bt = $(b).text();
          return (at > bt) ? 1 : ((at < bt) ? -1 : 0);
        });
        options.appendTo("#nameList");
      },
      error: function (xhr, status, error) {
        var err = eval("(" + xhr.responseText + ")");
        alert(err.Message);
      }
    });
  }
}
</script>

```

GS-qClcv=yPS \$zPCUf-sqez H^zS^ Hbqe-qzY~e@-zCbHzPCebS^zs Yszi

y PC sCb^@ p-<bq@-LC zb 4C @fObeC@> ..CqC zPC rSL^-Y@SeY%o y PS e-LC ~sCs zPC
K bbLYC ; P-qzs ..C4CqfS-C zb @q... -^@ @SeY%@-z-i y PC " qsz S0q zSb^ sC^z - sz-zS<
e-LS^-zC> z%eC -^@ ebS'zS@ zb zPC ; ` 4- <V@^@> ..PSP S^ z-q^ | ~CqS@ zPC Kq-ePk X
, dR y PC qCseb^sC ..CqC zPC^ ~sC@ zb qCq... zPC sSL^-Ys b^ zPC K bbLYC <P-qzi y PS ...s
@b^C-s- edpbHbHb^<Cez>- ^@zPC^Ctz szCe ...s zb qCeG-z zPC ecb<Csz>zb LCz - <b^zS^-- YP%
-e@-zS'L @SeY%bH@-z-i ,, PC^ zPCLq-eP ...s HYP%b^<zSb^-Y-~sCq seC-S @e-q \ CzCq
^C@C@ zb 4C S eY\ C^zC@s~<P -s sSL^-Yz%eC> ^-\ 4Cq bHS^L^-Ys zb @SeY%o ^@..PSP
ebS'z zPC sSL^-Ys -qC qY-zC@ zbi y PC e-LS^-zC ...s @CSL^C@-s - @peCb..^ \ C^~ ...SP
- f-Y-C bHI zb cCE S^ S^<q\ C^zs bHI i rSL^-Yz%eC -^@ ebS'zS@ ...s zCtz4btCsi y PC
ebS'zS@ 4bt ..b~Y@-~zbQ Y S Hq@sC-zC@ Hb\ - ebS'z S^ zPC se-<C Ysz i yb S^<q- sC zPC
~sCqCteCqC^<C bHzPC sbH... q> zPCsC ..CqC <P-^LC@ zb Ysz>-s \ \ bqs S'L ebS'zS@ -^@
qY-zS'L z%eCs ..CqC @C\ C@S^H-C sS4Y\ y PC Lq-eP S^ b... -<CszS4Y zPcb-LP G <P se-<C>
-^@zPC se-<Cs ebS'zs -qC YszC@ S^ - @peCb..^ \ C^~i yb P-^@C sSL^-Yz%eCs>z%eCs -qC
-@@@ zb ebS'z \ Cz-@-z-i y PC \ Cz-@-z- S HZ<PC@>zPC z%eCs -qC Ctzq <zC@-^@ @SeY%@
S^ - @peCb..^ \ C^~i GS^-YP%o <PC<Mbt S -@@@ zb \ -V@ zPC Lq-eP --zb -e@zC
GS~qC Iicu S zPC rSL^-Y? SeY%4- <V@^@ GS~qC IicD> S zPC Uf-s<qez qCseb^sS4Y Hbq
@q...S'L zPC S^S YsP-eC bHzPC Lq-eP> Y^Cs>sS C-Y 4C>Cz i GS~qC Iic> S qCseb^sS4Y
Hbq qC@q...S'L zPC@-z- S^ zPCLq-eP>-^@ @bCs sb 4%q\ ~CszS'L @-z- Hb\ zPC ; ` 4- <V@^@
fS , T, t q\ ~Cszs

```

public class SignalDisplayModel : PageModel
{
    private readonly DFourConsumer _consumer;
    public Space space;
    public Point point;
    public List<Point> points = new List<Point>();
    public List<Signal> signals = new List<Signal>();
    0 references
    public SignalDisplayModel(DFourConsumer consumer)
    {
        _consumer = consumer;
    }
    0 references
    public void OnGet()
    {
    }
    0 references
    public JsonResult OnGetSpace(string id)
    {
        _consumer.EstablishCredentials();
        space = _consumer.GetSpace(id).Result;
        return new JsonResult(space);
    }
    0 references
    public JsonResult OnGetPoint(string id)
    {
        _consumer.EstablishCredentials();
        point = _consumer.GetPoint(id).Result;
        return new JsonResult(point);
    }
    0 references
    public JsonResult OnGetUpdateSignals(string id, string type, int paginate)
    {
        _consumer.EstablishCredentials();
        signals = _consumer.GetSignals(id, type, paginate).Result;
        return new JsonResult(signals);
    }
}

```

GS~qC l icu=y PS\$ " L~qC @CeSzs zPC 4- <W0^@ bHzPC r S^ - Y? SseY%o

{u

```
<script src="https://ajax.googleapis.com/ajax/libs/jquery/3.6.0/jquery.min.js"></script>
<script type="text/javascript" src="https://www.gstatic.com/charts/loader.js"></script>
<script type="text/javascript">
  google.charts.load('current', { 'packages': ['corechart'] });
  google.charts.setOnLoadCallback(drawChart);

  function drawChart() {
    var data = new google.visualization.DataTable();
    data.addColumn(['datetime', 'Time']);
    data.addColumn('number', 'Value');

    var options = {
      title: 'Signals',
      curveType: 'function',
      pointsVisible: true,
      lineWidth: 3,
      legend: 'none',
      hAxis: { title: 'Time' },
      vAxis: { title: 'Data' },
      width: '100%',
      height: '100%',
      chartArea: { width: '85%', height: '75%' }
    };

    var chart = new google.visualization.LineChart(document.getElementById('curve_chart'));

    chart.draw(data, options);
  }
</script>
```

GS~qI icD=y PS \$ zPC U f- s<@z <@C q seb^s4YC Hbq S'SS W%@q...S'L zPC eYzi

```
function updateChart(id, type, paginate) {
  if (id != null) {
    $.ajax({
      type: 'GET',
      dataType: 'json',
      contentType: 'application/json',
      data: {
        id: id,
        type: type,
        paginate: paginate
      },
      url: '/SignalDisplay?handler=UpdateSignals',
      success: function (result) {
        var data = new google.visualization.DataTable();
        var items = result;
        data.addColumn(['datetime', 'Time']);
        data.addColumn('number', 'Value');

        for (var i = 0; i < items.length; i++) {
          var item = items[i];
          data.addRow([item.timestamp, Number(item.value)]);
        }

        var options = {
          title: 'Signals',
          curveType: 'function',
          pointsVisible: true,
          lineWidth: 3,
          legend: 'none',
          hAxis: { title: 'Time' },
          vAxis: { title: 'Data' },
          width: '100%',
          height: '100%',
          chartArea: { width: '85%', height: '75%' }
        };

        var chart = new google.visualization.LineChart(document.getElementById('curve_chart'));
        chart.draw(data, options);
      },
      error: function (xhr, status, error) {
        var err = eval("(" + xhr.responseText + ")");
        alert(err.Message);
      }
    });
  }
}
```

GS~qClic=y PS \$ zPC U f-s<qz H^<zS^ qseb^sS^NC Hq q@q ..S^L zPC eYz ..SP ^C...@-z-i

{_

y PC " ^-Yp-<bq@-LC bHzPC ..C4Qee\<-zsb^ \$ zPC -@ S'Szq zsb^ e-LQ yPS e-LC \$
~s0@ zb <q-zC bq @CzC se- <C> s-4Qe- <C> -^@ ebS'zs> bq -@@ -^@ q\ bfc ebS'z z%CS
Hb\ zPC \ Qz-@z-i yPC e-LC <b^z-S's - @peCb..^ \ C^~>..PSP \$ ~s0@ zb s0Cz zPC
@Csb@- <zsb^i r0C-zS'L -^ - <zsb^ zPC^ qfC-Ys P@C^ Oy [X ..SP - <zsb^ qf-zC@S'e-zi
r0C-zS'L - @S Cq^z - <zsb^ P@Cs zPC Oy [X -^@ qfC-Ys zPC Oy [X qf-zS'L zb zPC ^C..%
s0CzC@- <zsb^i , Y- <zsb^s ..bqMb^ zPC s- \ Ceq^ <eY=b^ - 4-zzb^ <VWzPC e-LCz-VW
@z- Hb\ zPC qf-zS'L zCz@btCs> @peCb..^ \ C^~> -^@ Y4C> -^@ sc^es - qd -Cz
zb zPC; ` 4- <VW^@ R^ z-q^>zPC; ` 4- <VW^@ I -C@Cs zPC Kq ePk X , dR Gs-qC Ii|CE
@eSzs zPC szq-<z-q bHzPC -@ S'Szq zsb^ e-LC 4- <VW^@ S^<Y-@S'L sCfCq YH^ <zsb^ si
yPCsCH^ <zsb^s -qzqfLLCq@fS , T, t qd -Czs Hb\ zPC Hb^zC^@ Gs-qC Ii|c @eSzs
zPC Oy [X qf-zS'L zb zPC " qsz z.b -@ S'Szq zSfC - <zsb^s>; qC-zC re-<C -^@; qC-zC
r~4@e-<Q Gs-qC Ii|| \$ zPC Uf-s-qez -^@, T, t 4Cb^LS'L zb zPCsC - <zsb^ si BfCq%
-@ S'Szq zSfC - <zsb^ P-s Sz s b..^ Uf-s-qez H^ <zsb^ -^@, T, t qd -Czi

} e ~^zS/zPS ebS'z S' zPC @fCbe\ C^z>zPCzC^ -^z R? -^@zC^ -^z V%~s0@Hbq -zPC^zS- Q
zsb^ -z? S C^s^ Gb-qP-s 4C^ S'SS zC@S' zPC..C4 -ee\<-zsb^ sCz-ei<s" YD yPS \ G^s
zPC C^@Q-sCqP-fCzb \ b@%zPC sb-qC <b@C bHzPC ..C4 -ee zb -<<Css zPCsq szbq@se- <C>
ebS'zs>-^@ sL^-Yi yb S^<qC-sC} t>sCsb^ f-qf 4YCs ...s -@@@zb szbqCzPC R? -^@V%
Hbq -sC..SP zPC Oy yd <VW^zi yPC S^@Ct e-LC bHzPC ..C4 -ee\<-zsb^ ...s \ b@S C@..SP
S'e-zs Hbq R? -^@V%~ Yb..S'L zPC C^@Q-sCq zb @C^Y qCzPCsq b..^ <qC@C^zS Ysi Gs-qC Ii|
@eSzs zPC 4- <VW^@ bHzPC R^@Ct e-LC> ..PCqC zPC -sCq s-4\ SzC@, dR <qC@C^zS Ys -qC
@C^Y qf@-s sCsb^ f-qf 4YCs Gs-qC Ii|J \$ zPC Uf-s-qez -^@, T, t qd -Cz qseb^sSVC
bHzq ^sebqS'L zPC, dR <qC@C^zS Ys Hb\ zPC Hb^zC^@ zb zPC 4- <VW^@


```
public class AdminPanelModel : PageModel
{
    private readonly DFourConsumer _consumer;
    public List<Space> spaces = new List<Space>();
    public List<string> typeList = new List<string>();
    public Space space;
    public Point point;
    0 references
    public AdminPanelModel(DFourConsumer consumer)
    {
        _consumer = consumer;
    }
    0 references
    public void OnGet()
    {
        PrepSpaces();
    }
    1 reference
    public List<Space> PrepSpaces()
    {
        _consumer.EstablishCredentials();
        spaces = _consumer.GetTopLevelSpaces().Result;
        return spaces;
    }
    0 references
    public JsonResult OnGetSpace(string id)
    {
        _consumer.EstablishCredentials();
        space = _consumer.GetSpace(id).Result;
        return new JsonResult(space);
    }
    0 references
    public JsonResult OnGetCreateSpace(string spaceName, string parentId)
    {
        _consumer.EstablishCredentials();
        if(parentId == null)
        {
            parentId = "";
        }
        bool successState = _consumer.CreateSpace(spaceName, parentId).Result;
        return new JsonResult(successState);
    }
    0 references
    public JsonResult OnGetCreatePoint(string pointName, string parentId)
    {
        _consumer.EstablishCredentials();
        bool successState = _consumer.CreatePoint(pointName, parentId).Result;
        return new JsonResult(successState);
    }
}
```

GS~qC|i|EeyPS" L~qC qCqCsC^zs zPC 4- <W@^@bHzPC, @\ S` d-LQ

```

<h1>Admin Panel</h1>
<p>Please select an action from the menu:</p>
<select id="actionSelect" name="actionSelect">
  <option style="display:none" disabled selected-- Select Action --</option>
  <option value="createSpace">Create Space</option>
  <option value="createSubSpace">Create Subspace</option>
  <option value="deleteSpace">Delete Space</option>
  <option value="createPoint">Create Point</option>
  <option value="updateAddTypePoint">Add Signal Type to Point</option>
  <option value="updateRemoveTypePoint">Remove Signal Type from Point</option>
  <option value="deletePoint">Delete Point</option>
</select>
<div id="createSpaceDiv" style="display: none;">
  <h4>Create Space</h4>
  <label>Space Name:</label>
  <input type="text" id="createSpaceInput" name="createSpaceInput" /><br />
  <button id="createSpaceButton" onclick="createSpace()">Create</button>
</div>
<div id="createSubSpaceDiv" style="display: none;">
  <h4>Create Subspace</h4>
  <div class="row">
    <div class="column" style="padding-left:50px">
      <label>Current Selected Parent Space:</label>
      <label id="subSpaceParentNameLabel"></label>
      <label id="subSpaceParentIdLabel" style="display: none;"></label><br />
      <label>Sub Space Name:</label>
      <input type="text" id="createSubSpaceInput" name="createSubSpaceInput" /><br />
      <button id="createSubSpaceButton" onclick="createSubSpace()">Create</button>
    </div>
    <div class="column" style="padding-left:50px">
      <p>Please select a parent space from the list:</p>
      <foreach (var item in Model.spaces)
      {
        SubList(item);
      }
    </div>
  </div>
</div>
</div>

```

GS-qC|i|c=y PS\$ \$ zPC Oy [X bHzPC" qz z..b -@ S'Szq zSfC - <zS^s>-s ..CY -s zPC - <zS^ sCG-zbcj

```
function createSpace() {
    var spaceName = document.getElementById("createSpaceInput").value;
    if (spaceName != null) {
        var parentId = "";
        $.ajax({
            type: 'GET',
            dataType: 'json',
            contentType: 'application/json',
            data: {
                spaceName: spaceName,
                parentId: parentId
            },
            url: '/AdminPanel?handler=CreateSpace',
            success: function (result) {
            },
            error: function (xhr, status, error) {
                var err = eval("(" + xhr.responseText + ")");
                alert(err.Message);
            }
        });
    }
}

function createSubSpace() {
    var spaceName = document.getElementById("createSubSpaceInput").value;
    var parentId = document.getElementById("subSpaceParentIdLabel").innerHTML;
    if (spaceName != null && parentId != null) {
        $.ajax({
            type: 'GET',
            dataType: 'json',
            contentType: 'application/json',
            data: {
                spaceName: spaceName,
                parentId: parentId
            },
            url: '/AdminPanel?handler=CreateSpace',
            success: function (result) {
            },
            error: function (xhr, status, error) {
                var err = eval("(" + xhr.responseText + ")");
                alert(err.Message);
            }
        });
    }
}
```

GS~qCl i|| =y PS \$ zPC U f -s < qez 4PS^@ zPC " qz z. b - @ \ S' Szq - zS^s>; qG-zCre-<C-^@; qG-zC
r~4Qe-<d

```

public class IndexModel : PageModel
{
    private readonly ILogger<IndexModel> _logger;

    0 references
    public IndexModel(ILogger<IndexModel> logger)
    {
        _logger = logger;
    }

    0 references
    public void OnGet()
    {
    }

    0 references
    public void OnGetCreateCredentials(string tenantId, string tenantKey)
    {
        Console.WriteLine(tenantId);
        Console.WriteLine(tenantKey);
        HttpContext.Session.SetString("Tenant Id", tenantId);
        HttpContext.Session.SetString("Tenant Key", tenantKey);
    }
}

```

GS~qC|i|{=y PC 4- <V0^@bHzPCR^@Ct e-LQ

```
<div class="text-center">
  <h1 class="display-4">Welcome</h1>
  <p>Get an overview of your spaces and points, or plot signals for monitoring.</p><br /><br />
  <p>Please enter valid credentials before continuing:</p><br />
  <label>Tenant ID:</label>
  <input type="text" id="tenantIdBox" /><br />
  <label>Tenant Key:</label>
  <input type="text" id="tenantKeyBox" /><br />
  <button onclick="createCredentials()">Set Variables</button>
</div>
<script src="https://ajax.googleapis.com/ajax/libs/jquery/3.6.0/jquery.min.js"></script>
<script>
function createCredentials() {
  var tenantId = document.getElementById("tenantIdBox").value;
  var tenantKey = document.getElementById("tenantKeyBox").value;
  console.log(tenantId);
  console.log(tenantKey);
  if (tenantId != null || tenantKey != null) {
    $.ajax({
      type: 'GET',
      dataType: 'json',
      contentType: 'application/json',
      data: {
        tenantId: tenantId,
        tenantKey: tenantKey
      },
      url: '/Index?handler=CreateCredentials',
      success: function (result) {
      },
      error: function (xhr, status, error) {
        var err = eval("(" + xhr.responseText + ")");
        alert(err.Message);
      }
    });
  }
}
</script>
```

GS~qCl|J=y PS \$ zPC U f- s<@ez Hbq @C<Y q\$`L , dR<q@C^zS Ysi

6 Python Library

y PC d%zPb^ XStq q%o. bqM b^ - sS eY e q\ S C bHsC^@S^L Ubb^ szqS^Ls zb zPC K q ePk X eY%uop~^@>fS SzS} pXi y PCUbb^ szqS^L <b^z- S's sCfCq YeSC-Gs bH@ z->s~<P - s zPCI ~Cq%o @ z- f- Y- Cs s~<P - s szqS^Ls- ^@S^zL Cq>- ^@zPCPG- @Cq y PCI ~Cq%S seC-S <HbqG <P z%oC bHqD ~Czi y PCI ~Cq%S SzCHS^ - Ubb^ Hbq\ - z>- ^@S zPC <b\ \ - ^@bqH^<zSb^ ..PS-P zPC K q ePk X eY%uop~^@S zb CtC- zD y PC @ z- f- Y- Cs S^ zPC Ubb^ szqS^L - qC - -zb\ - zS- Y%o eY <@S^ zPCI ~Cq%oy PCPG- @Cq <b^z- S's zPCzC^ - ^z S@ - ^@zC^ - ^z zbV^>..PS-P @CzCq\ S^Cs %b-q e qf SCLCs Hbq qC @S^L - ^@..qzS^L @ z- i y PC d%zPb^ XStq q%ob^z- S's cEH^<zSb^> _ bH..PS-P - qC @CSL^C@ zb 4C ~sC@ 4%zPC ~sCq ..PSC zPC Y- sz S\$ ~sC@ 4%o Y zPC bzPCq H^<zSb^>s zb sC^@Oy y d qD ~Cszs zb ? S C^Sb^ Gb-qj

y PC " qsz H^<zSb^ bHzPC YStq q%S zPC <qC- zC E PG- @Cq H^<zSb^>i y PS H^<zSb^ z- VIs zPC zC^ - ^z R? - ^@zC^ - ^z V%o s szqS^L e- q\ CzCq>- ^@qz~q's S\$ - s - @SzSb^ - q%szq- z- qD y PS szq- z- qC S\$ ~sC@ 4%o Y H^<zSb^>s ..PS-P qD ~Cszs @ z- Hbq\ ? S C^Sb^ Gb-qj y PC sC-b^@ - ^@zPSq@H^<zSb^>s - qC <qC- zC E se- <C - ^@ <qC- zC E ebS^z qCseC-zfC%o; qC- zC re- <C z- VIs - ~sCq @C^ @ se- <C ^- \ C S^ zPC Hbq\ bH- szqS^L> - Yb^L ..SZP - PG- @Cq @SzSb^ - q%o ^@zPC? S C^Sb^ Gb-qeY%uop~^@} pX>- ^@Csz- 4YSPCs - ^C..se- <D ; qC- zC dbS^z z- VIs - ebS^z ^- \ C - ^@zPC se- <CR? bHzPCE- qC^z se- <C>- s szqS^Ls>zPCz- q.Cz } pX - ^@zPCPG- @Cq>- ^@Csz- 4YSPCs - ebS^zi

G~^<zSb^ Hb-q> <qC- zC E sL^ - Y > <qC- zCs - ^C..sL^ - Y ~^@Cq - ebS^zi Rz z- VIs sCfC^ f- qD - 4YCs> f- Y- C - ^S> sL^ - Y e z%oC zS Csz- \ e> ebS^zE S@ - ^@z- q.Cz> ..PS-P - qC - Y szqS^Ls> - ^@PG- @Cq>..PS-P S\$ - @SzSb^ - q%oy PC H^<zSb^ <b\ 4S^Cs zPC " fC " qsz f- qf 4YCs ..SZP - K q ePk X l ~Cq%o ^@sC^@s - ^ Oyy d qD ~Csz zb zPC z- q.Cz>- Yb^L ..SZP zPC PG- @Cq

G~^<zSb^ " fC> sSf> - ^@ sCfC^ - qC - Y ~sC@ Hbq YszS^L se- <Cs> ebS^zs> - ^@ sL^ - Y i y PC sC - qC YszE se- <Cs > YszE ebS^z >- ^@ YszE sL^ - Y qCseC-zfC%oy PC Xsz re- <Cs H^<zSb^ Yszs - Y se- <Cs - f- S^ 4Y zb zPC ~sCq> ..PSC zPC Xsz dbS^zs H^<zSb^ Yszs - Y ebS^zs - ^@ zPCsqe- qC^z se- <Cs i 3bzP bHzPCsC H^<zSb^ z- VIs z..b f- qf 4YCs>zPCz- q.Cz szqS^L - ^@zPC PG- @Cq @SzSb^ - q%o Xsz r S^ - Y Yszs zPC Y- zCsz cEEsL^ - Y S^ - ebS^zi y PS H^<zSb^ z- VIs - ebS^z R? szqS^L>- z- q.Cz szqS^L - ^@- PG- @Cq @SzSb^ - q%o s f- qf 4YCs

G~^<zSb^ CSLPz> qCzqCfC E Y- zCszE sL^ - Y > S\$ ~sC@ zb qCzqCfC zPC f- Y- Cs Hbq\ zPC Y- zCsz sL^ - Y S^ - ebS^zi y PS H^<zSb^ z- VIs Hb-q f- qf 4YCs y PC " qsz S\$ - szqS^L bHzPC ebS^z S@ zPC ^Ctz zPC z- q.Cz } pX szqS^Li y PS @%zPC PG- @Cq @SzSb^ - q%oy PC Hb-qP f- qf 4YCs - 4bbY C^ Hbq qCz- q^S^L - @SzSb^ - q%szq- z- qC bHzPC sL^ - Y

G~^<z\$^ ^S^CS - sS eYCs-fCH^<z\$^i s-fC@-z- z-VLs z.b f-q\$ 4YCs>zPC@-z- zbQ1CQ
s-fC@-s - szq\$^L>-^@- 4bbY^ ^ zb @C-S@C s-fC Hbq\ -zi yPC ~sCq\ -%PbbsC zb s-fC -s
CSzPCq - i<sf bqilb^>@CeC^@S^L b^ SHzPC%o.- ^z zb s-fC @Sz\$^ -q%szq<-z-qSi

G~^<z\$^ zC^> sC^@€ebsz \$ - ebszS^L H^<z\$^>-sC@ 4%bzPCq H^<z\$^s zb sC^@Oy y d
qd ~Cszs zb ? S C^s\$^ Gb-qj Sz z-VLs zPqCf-q\$ 4YCs=z-qLz } pX szq\$^L>zPCI ~Cq%b4UCz>
-^@zPCPG-@Cq @Sz\$^ -q%Rz sC^@s zPC qd ~Csz -^@... SzS Hbq zPC qCseb^sC Rz ..SY <-z-P
Ct<Cez\$^s -q\$S^L Hb\ 4-@qd ~Cszsi

6.1 Python Examples

y b - \$@ .. SzP fS~- YS^L zPC ~sC <- sCs Hbq zPC d%Pb^ YS4q q%asCfCq YCt-\ eYCs \$ edpfS@C@
y PC " qsz Ct-\ eYCs - <b^zS^-b-s ebszS^L d%Pb^ s<qezi yPS Ct-\ eYCs z-VLs - q ^@b\
^~\ 4Cq 4Cz..CC | u{ -^@{CEE- ^@<qG-zCs - sS^ -YS^ - seC-S C@ebS^zi yPC sC<b^@s<qeZ
S- sS eYCs q@H^<z\$^>..PSP qC-@s - f-Y-CGfCq%eESC<b^@si yPCzPS@Ct-\ eYCs <qG-zCs
- se- <G>..PSCzPC Hb~qP SY-szq zCs - s-fS^L H^<z\$^i y PC " H^P -^@" ^-YCt-\ eYCs^ zPC
Ct-\ eYCs " YC \$ YbLLCq>..PSP @q..s - e%Ybz bHzPC Y-sz cCEESL^-Ys S- ebS^zi , WzPCSC
Ct-\ eYCs \ -%4CHb~^@S^ zPCK S@-4 qCebSzbq%a C^z\$^@S^ Iici

7 Arduino Library

y PC , q@-S'b X\$4q q%\$S YL PzCq S' H^<z\$^s zP- ^ zPC d%zPb^ X\$4q q%@-C zb zPC sS C Y\$ S-z\$^ bH, q@-S'b \ C\ bcf%? -Czb ~^S@C^zS C@eqp4Y\ s>zPC Y\$4q q%o. SYb^Y%b^<z\$^ b^ zPC, q@-S'b } ^b ,, S\$S qCfi| bq zPC [V p sCqCs bH, q@-S'bsi ,, PC^ ~sS'L zPC Y\$4q q%o rdRP > ,, S\$S R] , iP > , q@-S'bTsb^iP >- ^@ , q@-S'bOzze; YC^ziP \ ~sz 4CS^<Y-@C@ S' bq@Cq Hbq S' zb H^<z\$^ eqpeCq%o, ^ S'sz- ^<C bHzPC Y\$4q q%\$s zPC^ sS eY%oqC-zC@ yb SY-szq zC> S' <- ^ 4C S'sz- ^zS zC@ YV zPS= ? S' C^s\$^Gb-q eS@Hb-qi y PS <qC-zC- ^ S'sz- ^<C ^-\ C@ @Hb-qi

y PC Y\$4q q%o<b^z-S's { H^<z\$^s> b^C Hbq sCz-e>b^C Hbq sC^@S'L>- ^@ b^C Hbq qC-CY'S'L sS ^-Yi y PC sCz-e H^<z\$^ S' <Y@ S'Sr zqC \ - ^@ S' ~sC@ zb e-ss zPC rCqS Y- ^@ Oy y d <YC^z zb zPC Y\$4q q%o y PS H^<z\$^ \ ~sz -Y.-% 4C eCqHbq C@ S' bq@Cq Hbq zPC Y\$4q q%zb l ~Cq%zPC? S' C^s\$^ Gb-q K q ePk X , dR yb SY-szq zC zPC ~sC bHzPS H^<z\$^> S' - s%zC .. PCq zPC Y\$4q q%P-s 4C^ S'sz-zS zC@-s @Hb-q >zPC sCqS Y-s rCqS Y>- ^@zPC Oy y d <YC^z -s <YC^z ><- YzPC H^<z\$^ YV zPS= @Hb-q S'Sr zqC \ f. rCqS Y>. <YC^zgt i y PC sC^b^@H^<z\$^ ..b-Y@zPC^ 4C<- Y@-s= @Hb-qj G @X-zCsr S'^-YfebS'zR>zC^- ^zR> zC^- ^zV C%oSqfCqgt >..PCq zPC ^b^@4f\$-s sCqfCq S' zPC ? S' C^s\$^ Gb-q eY%oqC~^@ } pX= S'zi@S' C^s\$^Hb-q\$ i , YS'e-zs -qC szqS' Lsi y PS H^<z\$^ l ~CqCs zPC K q ePk X , dRHbq zPC Y-zCz f-Y-C S' - ebS'z - ^@qz-q's - • b-zi GbYb..S'L zPC C^-\ eYCs bHzPC z..b eqCf\$-s H^<z\$^s> zPC zPS@H^<z\$^ S' <Y@ 4% @Hb-qj dbsr S'^-YfS'^-Y-zS' Csz-\ e> ebS'zR>zC^- ^zR> zC^- ^zV C%oSqfCqgi R'e-zs sP-q@ ..S'P zPC qC-@H^<z\$^s -qC zPC s-\ C>..PSC sS ^-YS - • b-z qCeqC^zS'L - \ C-s-q@f-Y-C- ^@zS' Csz-\ e S' - szqS' bH zPC zS' C bH<qC z\$^ Hbq s- S@ sS ^-Y B^-\ eYCs ~sS'L zPC Y\$4q q%o-V^L ..S'P zPC Y\$4q q%o SsOH<- ^ 4C Hb-^@S' zPC LSP-4i<b\ qCebS'zbq%oS'V@ zb S' <P-ezCq l ici

8 ASP.net Web-Application

} eb^ - <<C\$S^L zPC , rdi^Cz ..C4Qee\%-z\$^>zPC S^@Ct e-LC -sV\$ Hbq ? S^ C^s\$^ Gb-q <q@C^zS Ys yPCs^@Ct \$ @SeY%@S " L~qCDici Ob...zb LCz zPCsC <q@C^zS Ys -qC CteY S^C@ S^ <P-ezCqJilji yPCzC^ ^z \ ~sz P-fCs~' <C^z eCq\ Sss\$^s zb eCqHbq\ -Y- <z\$^s zPcp~LP zPC ..C4Qee\%-z\$^i yPC \ -S^ H^<z\$^s bHzPC ..C4Qee -qC -<<C\$C@ zPcp~LP , @ S^ d-^CY -^@ re-<C\$ b^ zPC PC-@CqI-qj } eb^ - <<C\$S^L zPC , @ S^ d-^C^>zPC -sCq \$ sPb..^ - @pe@b..^ \ C^~i yPS \ C^~ b^z- S^s zPC sCfC^ -@ S^Szq-z\$C -<z\$^s bHzPC ..C4Qee\%-z\$^i yPCsC-qC=; qC-zCre-<C>; qC-zCr~4Qe-<C>? CQCzCre-<C>; qC-zCdbS^z> , @@dbS^z r\$^~Yy%@C>pC bfcdbS^z r\$^~Yy%@C>? CQCzCdbS^zi

„ PC^ sOCzS^L ; qC-zCre-<C>zPC -sCq ..SY4C -sV@zb C^zCq - ^-\ C Hbq zPC se-<CzBQICQ \ -@ „ PC^ zPC^-\ CzCtzCqbt \$ " YC@zPC -sCq <YsV\$ zPC ; qC-zC 4-zzb^ zb <qC-zCzPC se-<C yPS <qC-zC - ^C..zbeOCfCY se-<C G\$~qC DiI sPb..s zPC @SeY%Hbq zPS -<z\$^i yb <qC-zC - s-4Qe-<C>sOCz zPC; qC-zCr~4Qe-<C -<z\$^i yb eCqHbq\ zPS -<z\$^>- -sCq \$ -sV@zb ^-\ CzPC se-<C>-^@sOCz - e-qC^z se-<C Htp\ zPC qC~qsfC Ysz b^ zPC q\$LPzQ P-^@s@C yPC ..C4Qee\%-z\$^ ^bzS C\$ zPC -sCq bHzPC <~qC^zY%@CzC@e-qC^z se-<C a ^<CzPC^-\ Cqbt -^@- e-qC^z se-<C P-s 4C^ sOCzC@>zPC -sCq <-^ <qC-zC - s-4Qe-<C ..SZP zPC ; qC-zC 4-zzb^i G\$~qC Div @CeSzs zPS @SeY%or Pb-Y@zPC -sCq ..SZP zb @CQC - se-<C Hbq -^%qC sb^>zPC%<-^ ~sC zPC ? CQCzCre-<C -<z\$^i yPC ? CQCzCre-<C -<z\$^ qd -sCq zPC -sCq zb sOCz - se-<C Htp\ - Ysz>YsV\$ S^ zPC eqfSb-s -<z\$^i rOCz - se-<C Htp\ zPC qC~qsfC Ysz>@SeY%L 4bzP zbeOCfCY se-<C\$ -^@s-4Qe-<Csi yPC <~qC^zY% sOCzC@se-<C \$ @SeY%@>zb -fb\$~^@C\$C@@Cz\$^ bHse-<Csi a ^<C- se-<C \$ sOCzC@> zPC -sCq \ -%@CQC \$..SZP zPC ? CQCz 4-zzb^i G\$~qC Diu @CeSzs zPC @SeY%Hbq zPS -<z\$^i

rPb-Y@ zPC -sCq ..SZP zb <qC-zC - ebS^z>zPC%<-^ ~sC zPC ; qC-zC dbS^z -<z\$^i a ^<C sOCzC@>zPC%<@C-sV@zb " Ys^ - ^-\ C Hbq zPC ebS^z>-^@sOCz - e-qC^z se-<C Htp\ zPC q\$LPzQ-^@s@C Ysz i yb <qC-zC zPC ebS^z>eqss zPC ; qC-zC 4-zzb^i G\$~qC DiD @CeSzs zPS @SeY%oyb @CQC - ebS^z>sOCz zPC ? CQCz dbS^z -<z\$^i rOCz zPC e-qC^z se-<C bH zPC ebS^z S^ zPC q\$LPzQ-^@ Ysz>zPC^ sOCz zPC ebS^z zBQIC@CzC@ Htp\ zPC @pe@b..^ \ C^~ b^ zPC YCzi ; YsVzPC ? CQCz 4-zzb^ zb @CQC zPC ebS^zi G\$~qC Dic @CeSzs zPS -<z\$^i r\$^~Yy%@C\$ -sC@ ..SZPS^ - ebS^z -qC szbq@ S^ zPC ebS^z \ Cz-@-z-i yb -@@- s\$^~Yy%@Czb - ebS^z>sOCz zPC , @@dbS^z r\$^~Yy%@C yPC -sCq zPC^ sOCz zPC ebS^z s e-qC^z se-<C b^ zPC q\$LPzQ-^@ Ysz>zPC^ zPC ebS^z S^ zPC @pe@b..^ \ C^~>zPC^ C^zCq zPC s\$^~Yy%@C S^ zPC zCtzCqbt i yPC^ ~sC zPC , @@ 4-zzb^ zb -@@ zPC s\$^~Yy%@C zb zPC ebS^z \ Cz-@-z-i G\$~qC Di_ @CeSzs zPS @SeY%oyb q\ bfc - s\$^~Yy%@C Htp\ zPC

Welcome

Get an overview of your spaces and points, or plot signals for monitoring.

Please enter valid credentials before continuing:

Tenant ID:
Tenant Key:

GS~qDc=yPS \$ zPCR^@Ct e-LC bHzPC..C4Qeei yPS \$ \$..PCqzPC ~sCq eqsC^zs zPCsq, dR<q@^zS Ysi

\ Cz-@z->sCCz zPC p\ bfC dbS'z rSL^~Yy%eC-<zS^i rCCz zPC e-qC^z se-<C Htp\ zPC
se-<Cs Ysz>zPC^ zPC ebS'z Htp\ zPC ebS'zs @pe@b..^ \ C^~i GS^~Y%oSCz zPC sL^~Y
z%eCzb q\ bfC>zPC^ ~sCzPC p\ bfC 4~zbi GS~qDcCE@CeSzs zPC ~sCq S'zCqH<C Hbq
zPS -<zS^i

yb ~sCzPC\ b^Szb^L H^<zS^s bHzPC..C4QeeY~zS^><YsWb^ re-<Cs b^ zPC PC-@CqQ
4-q yPS q@sqz zPC ~sCq zb - e-LC @SeY%SL se-<Cs -^@ebS'zsi ,, PC^ - se-<C S
<YsW@>zPC Ysz qfC-Y zPC se-<Cs s-4Qe-<Cs> -^@zPC se-<Cs ebS'zs -q YszC@ S^ zPC
ebS'zs Ysz yPS ~sCq S'zCqH<C S @CeSzC@ 4%L-qDi|i yb @SeY%zPC sL^~Y 4Cb^LS'L
zb - se-<C -^@ Ss qseCz fC ebS'zs>@~4YQYsWzPC se-<C S^ zPC Ysz yPS q@sqz zPC
~sCq zb zPC Lq ePS- Y@SeY%Hbq sL^~Yi yb eYbz zPC sL^~Y>sCCz - ebS'z>sL^~Yz%eC>
-^@zPC ^~\ 4Cq bHsL^~Y zb @SeY%zPC^ zS^WzPC ~e@zC eYbz <PC^Mbt i XG fS'L zPC
<PC^Mbt <PC^W@..SYq@q...zPCeYbz CfCq%Cb^@ , ^%C...sL^~Y~eYb-@C@zb zPC ebS'z
..SYzPC^ 4C @SeY%@ dbS'z -^@sL^~Yz%eC<^ 4C <P-^LC@~qS'L ~sC-^@..SY 4C ~sC@
b^ zPC ^Ct z q@q...S'L bHzPC Lq ePi GS~qDc{ qeqsC^zs zPS @SeY%

Spaces and Points

Spaces

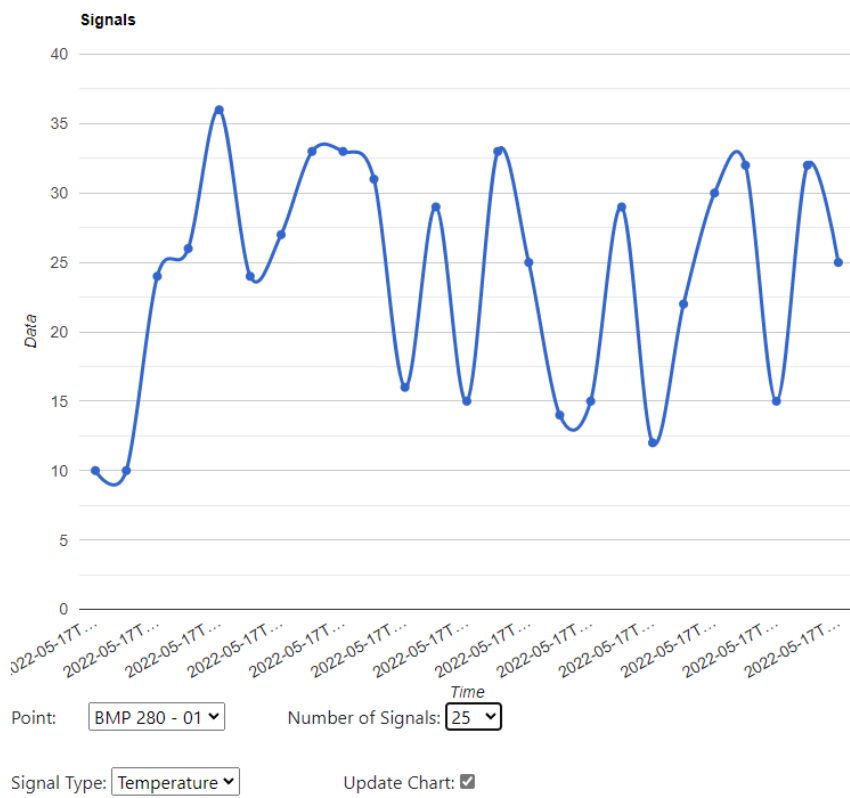
- Production Hall 1
 - Heater 1
 - Heater 2
- Production Hall 2
- usn-expo

Points

- BMP 280 - 01
- BMP 280 - 02
- BMP 280 - 03

GS~qCD|=yP\$ \$zPCre-<XSz e-LC bHzPC..C4Qeei rOCz - se-<Czb @SeY%ebS'zs - ^@sL^-Yi

Heater 1



GS~qD{=yPS S zPCr s^-Y? SeY%e-LQ OqCzPC ~sCq \ -%PbbsC ebs^zs - ^@s s^-Yz%Cs zb @SeY%o
Hp\ i

Admin Panel

Please select an action from the menu:

GS-qC DJ=y P\$ \$ zPC S'S\$ Y, @\ S'Szq-z\$^ e-LQ yPC -sCq \ -%sCC-z -^ -z\$^ zb eCq\ H\ zPC Y\$zi

Admin Panel

Please select an action from the menu:

Create Space

Space Name:

GS-qC DIl =y P\$ \$ zPC; qC-zCre-<C-z\$^ e-LQ

Admin Panel

Please select an action from the menu:

Create Subspace

Create Subspace

Current Selected Parent Space: Production Hall 2

Sub Space Name:

Create

Please select a parent space from the list:

- Production Hall 1
 - Heater 1
 - Heater 2
- Production Hall 2
- usn-expo

GS~qC Div=y PS S zPC; qG-zCr ~40e-<C-<zb^ e-LD yPC~sCq\ -%sCC-z - e-qC^z se-<CHp\ zPCqL PzQ
P- ^@ Szi

Admin Panel

Please select an action from the menu:

Delete Space

Delete Space

Current Selected Space For Deletion: Electrolysis Machine 1

DELETE

Please select a space from the list:

- Production Hall 1
- Production Hall 2
 - Electrolysis Machine 1
- usn-expo

GS~qC Div=y PS S zPC? CQzCre-<C-<zb^ e-LD

Admin Panel

Please select an action from the menu:

Create Point

Create Point

Current Selected Parent Space: Electrolysis Machine 1

Point Name: Mass Flow - 01

Create

Please select a parent space from the list:

- Production Hall 1
- Production Hall 2
 - Electrolysis Machine 1
- usn-expo

GS~qCDD=yPS\$zPC; qG-zCdbS^z - <zS^ e-LQ yPC~sCq\ -%sCCz - e-qC^z se-<CHp\ zPCqSLPzQ-^@
Ysz

Admin Panel

Please select an action from the menu:

Add Signal Type to Point

Add Signal Type to Point

Current Selected Parent Space: Heater 1

Point: BMP 280 - 01

Type: Temperature

Add

Please select a parent space from the list:

- Production Hall 1
 - Heater 1
 - Heater 2
- Production Hall 2
- usn-expo

GS~qCDi=yPS\$zPC, @@rS^~Yy%eC - <zS^ e-LQ

Admin Panel

Please select an action from the menu:

Remove Signal Type from Point ▾

Remove Signal Type from Point

Current Selected Parent Space: Heater 1

Please select a parent space from the list:

Point: BMP 280 - 03 ▾

Type: Temperature ▾

Remove

- Production Hall 1
 - Heater 1
 - Heater 2

- Production Hall 2

- usn-expo

GS~qC DcEey PS S zPC p \ bfCr S ^-Yy %C - <zS ^ e-LQ

Admin Panel

Please select an action from the menu:

Delete Point ▾

Delete Point

Current Selected Parent Space: Electrolysis Machine 1

Please select a parent space from the list:

Point: Mass Flow - 01 ▾

DELETE

- Production Hall 1
- Production Hall 2
 - Electrolysis Machine 1
- usn-expo

GS~qC Dicc=y PS S zPC ? CCzC dbS'z - <zS ^ e-LQ

9 Discussion

y PC eqplCz b4UCzsfC bHCs\ S'-zS'L zPC ^CC@ Hbq K q ePk X I -Cq%Wb..X@Lc>P-s 4CC^ s-' <SC^zY%ab\ eYzC@ y PC d%Pb^ XS4q q%ab^z-S's H^<zSb^s Hbq zPC \ bsz S\ ebqz-^z ~sC<-sCs>-Yb..S'L Sz zb 4C ~sC@-s-^-@ S'Szq zsfC zbbY>Hbq <qC-zS'L se-<Cs-^@ebS'zs> -s..CY-s 4CS'L @CeY%Q@S' d%Pb^ 4-sC@@z- -d ~SSzSb^ ~^Ss bq@z- eqC<Csbqsi y PC d%Pb^ XS4q q%Ss beC^Cb-qC-^@-f-S' 4YC-z zPCLSP~4 qCebSzbq%SSzC@S' <P-ezCqI ici R^ -@zSb^ zb zPS>zPC YS4q q%P-s 4CC^ @CeY%Q@ zb d^ dR-^@zP-s Ss -f-S' 4YCzPq~LP d%Pb^ s e-<WLC\ -^-LCq>dRd>-s @HeS

y PC, q@-S'b XS4q q%P-s -YeY ^^C@H^<zSb^ -Ys%Pb..CfCq>Sz ..SYb^Y%o.bqW..SZP ^C..Cq \ b@Cs ..PS-P P-s \ bqC \ C\ bq%zP-^ zPC, q@-S'b } ^bi y PS qCs-Y Ss s-4Q-q..SZP zPC eY ^^C@Hc-z-qCbH4CS'L ~^SfCq-Y4-z Sz S H^<zSb^ -Y^b^CzPCQssi y PC, q@-S'b XS4q q%S z.b ~sC<-sC H^<zSb^s -qC 4bzP beCq zSb^ -Y>-Yb..S'L Hbq zPC <qC-zSb^ bH, q@-S'bqI-sC@ Rby ?, k ~^Ssi y PC <qC-zSb^ bHqC @w.qzC S'zCq <zSb^ ..SZP zPC? S\ C'sSb^ Gb-q, dRP-s 4CC^ s-' <SC^zY%szqC\ Y^C@

3CS'L zPC 4SLCsz e-q bHzPC eqplCz> zPC, rdi^Cz ; bqC ..C4QeeYs<-zSb^ <b^z-S's -Y eY ^^C@Hc-z-qCsi, Y-@ S'Szq zsfC H^<zSb^s>-s..CY-s @SeY%Q-qC H-Y%beCq zSb^ -Y -^@qC-@%Hbq YS SzC@beCq zSb^si y PC..C4QeeYs<-zSb^ Y<Vb -<zSb^ qCeb^sC Hc@4- <Wzb zPC ~sCq..PS-P \ C^s Sz @bCs ^bz ^bzS%zPC ~sCq bHzPC b-z<b\ Cs bH@S Cq^z -@ S'SQ zq zsfC -<zSb^si y PS \ -%AC qPYC@b-z S' - YzCq SzCq zSb^ bHzPC-eeYs<-zSb^i

y PC qCebq @b<-\ C^zs zPC eY ^^S'L -^@ @CfCbe\ C^z bH, dRvXS4q qCs Hbq d%Pb^ -^@, q@-S'b>-^@ - ..C4QeeYs<-zSb^ ~sC@ Hbq \ b^SzbqS'L -^@ -@ S'Szq zSb^i y PC qCebq <b^z-S's>@Cs<qe zSb^s bHCssC^zS YzPC\ Cs>sb-qCs>@Cz-SC@...WQzPq~LPs bH@CfCbe\ C^z> -^@SY-szq zSb^s zb -S@..SZP CteY^-zSb^si y PC qCebq HbYb..s -^-z-q Y4qC Veb..^ bHzPC @CfCbe\ C^z <%ad y PC qCebq s-' <SC^zY%ab<-\ C^zs zPC eqplCz -^@ Ss @CfCbe\ C^zi

10 Conclusion

? -z- <bYc-zSb^>eqp<CssS^L - ^@szbq LC - qC GfCqS^<qC sS^L .. SzP S^@-szq%diCE K bb@sbY-Q zSb^s Hbq @z- P- ^@S^L - qC 4CS^L @CfClbeC@>4-z \ -%o^bz 4C - <<CssS4YC Hbq - YebzC^zS Y ~sCqsi y P\$ eqpLc-z S^zC^@C@zb \ -Vc- K q ePk X , dR- ^@szbq LC sbY-zSb^ \ bqC - <<CssQ S4YC- ^@P-s @b^Csbj y PCeqpLc-z P-s \ -@czPC sbY-zSb^ - <<CssS4YC zb d%zPb^ @CfClbeCqS - ^@ [-Vcqs >..Pb - qC S^CteCqC^<C@.. SzP K q ePk X>4-z - qC S^ ^C@bH- @z- eqp<CssS^L sbY-zSb^ Hbq zPCsq Rby eqpLc-zsi

y PCd%zPb^ X\$4q q%\$ @C\$S^C@S^ s~P -...%zP-z GfC^ S^CteCqC^<C@d%zPb^@qPLq \ \ CqS .. SzPb-z CtzC^sC Wb..X@LC bH@szSb^ - qC>Lsb^>bq K q ePk X>\ -%z-Vc H Y - @f- ^z-LC bH? S C^sSb^ Gb~qs sCqfS^C 3C Sz Hbq szq~z~qS^L se- <Cs bq Csz- 4YS^PS^L ebS^zs>bq YbL bq qd -Csz sS^ ^-Ysi rPb~Y@zPC ^C@- qC>S <- ^ GfC^ s-fC sS^ ^-Ys -s - i<sf bq iLsb^i ,, PSC zPC, q@-S^b X\$4q q%Y <Vb - ^%o @ S^Szq zSfCH^<zSb^>S S H^<zSb^ - YHbq <qC zS^L ? , k Q bq <b^zqP YCq^Ss>.. SzPb-z - ^%eqPq Wb..X@LC bH Lsb^ bq K q ePk Xi y Pb-LP S S ^bz H^<zSb^S^L .. SzP zPCebe~Yq, q@-S^b } ^b>S ..bqVb ..CY.. SzP ,, S\$SC^ - 4V@ @CfS^Cs .. SzP \ bq \ C bq%o

y PC, rdi^Cz ..C4Q eeYs- zSb^ s-eebqz - ^ - qf-%bH@S CqC^z -sCq - <zSb^s - ^@ @SeY%i , ^%o-sCq \ -%o^b...q^ zPS - eeYs- zSb^ - ^@ - <<Css ? S C^sSb^ Gb~qs sCqfS^C>L\$C^ zPC%o P-fC f-Y@ <qC@^zS Ysi y PC - eeYs- zSb^ L\$C^s - Lbb@ bfCqfS^.. bHse- <Cs - ^@ ebS^zs>- ^@ -Yb..s ~sCqS zb \ b^Sz bq YbLLC@ @z-i Rz S ^b... qC @%Hbq Ys SzC@ e~4Ys ~sC G-qP Cq @CfClbe\ C^z \ -%o^<Y-@C szqC\$CzS^L>4-L@P-^zS^L>sC~qz%eqp4S^L>@CfClbe\ C^z bH - ~^S -C sz%C sPCCz>- ^@ \ -Vb^L C^SzS^L <b@C \ bqC C <S^zi , ^%b^C...^zS^L zb ~sC ? S C^sSb^ Gb~qs K q ePk X , dR>S^<Y-@S^L zPC } ^SfCqS%bHr b-zPCB -szCq^] bq..%oS ^b...-4YC zb ~sC ? S C^sSb^ Gb~qs eqp@~zi

Bibliography

- Q: , i ri K SYSi „ P-z S\$ Sz fS'zCq^Cz bHzPS^Lsg- ^@Pb...@bCs Sz...bqMn f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwS^zCq^Cz bHzPS^Ls- LC^@ i zC-Pz- qL.Cz i <b\ w@CH^S^SzSb^w R^zCq^CzCbHdyPS^LsCRbyi
- Q: [lzz fCqSb^ l iCE f| CE_ g 9 ^Y^Ci , f- S' 4YC= Pzzes=vw@<si b- sSsCbeC^i bqlLw \l zzw\l zzw\l i CE\l zzw\l i CEPz\Yi
- Q: R O 4sP\ - ^i , <b\ eYzCL- S@C zb qsz - eS S^ Szi f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vw.....i.^- 4zbi <b\ w@CszQ- eSOSbzCL- S@Cw
- Q: , i V Cq^ C^>[i V bf- zs<P - ^@Vi O- qV\ p CszHY@CSL^ Hbq S'zCq^Cz bHzPS^Ls s%Q zC\ si f| CEug> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwzbbYsi SCzH bqlLwS@w@q- HzC\wq^ C^Q z| zqL.CqCszCSbzCEi Pz\Yi
- Q: K q-ePl Y6- l ~Cq%Y^ L-- LC Hbq %b-q - eS f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwv Lq- ePl Yi bqlLw
- Q: „ P-z S- sei^Cz <bqMn^Ci f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vw@z^Ci \S<qpsbHz i <b\ w@C^Q- swYC- q^wse^Cz w.P- zCSsQ- se^CzQ- bqQ
- Q: XG- q^ \ bqC QzPS^LseG- W\$zi f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwzPS^LseG- W\ <b\ w@- LCswYC- q^E\ bqQ
- Q: K q-H^- Hc-z- qS 6Lq-H^- Y 4si f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwLq- H^- i <b\ w@Lq- H^- vneY<\zEHbbzCqj
- Q: „ P-z S\$ LSP-4m- 4LS^Cqs S'zq@- zSb^ zb LSP-4i f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vwS^sz- i <b\ w@b.YO@LC+ sOw.P- zCSsQLSzP- 4iv
- Q: „ P-z S\$ - q@- S^bm6- q@- S^bi f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vw.....i. - q@- S^bi <<v@^vK- S@CwR^zq@- zSb^i
- Q: p- se4Cqf%eS Hb- ^@zSb^ Q- 4b-z ~si f| CE|cg> 9 ^Y^Ci , f- S' 4YC= Pzzes=vw.....i. q- se4Cqf%eSi bqlLw 4b-zw
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- Ql: Ob\ C6@S C^Sb^ Hb~q f|Ecg>9 ^S^Ci , f-S 4Y=Pzzes=ww@S\C^sSb^Hb~q Sbv
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Appendix A

Project Description

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FMH606 Master's Thesis

Title: Development of Open Source Datalogging and Monitoring Resources for IoT Platform

USN supervisor: Hans-Petter Halvorsen

External partner: Dimension Four

Task background:

USN uses different IoT platforms today in within the IT and Automation Bachelor program and the Industrial IT and Automation Master program, both for educational and research purposes.

Dimension Four (<https://dimensionfour.io>), a local company in Grenland Norway has developed a new IoT platform, which may be relevant to use by USN in the future. The IoT platform uses MQTT and GraphQL.

To use this platform at USN, both in education and research, APIs and practical examples need to be developed for different devices (PCs with DAQ devices from National Instruments, Arduino, and Raspberry Pi) and programming platforms. The main programming environments and programming languages at USN within the Bachelor/Master programs mentioned above are Visual Studio/C#, Python, LabVIEW, and MATLAB.

Task description:

In this project the following activities should be performed:

- Give an overview of existing IoT solutions for Datalogging and Monitoring. Azure and ThingSpeak are platforms used by USN today, but there exist many others that may be relevant to use in the future.
- Give an overview of different standards and protocols within IoT and compare and discuss advantages and disadvantages, some examples are REST, MQTT, and GraphQL. Industrial protocols like OPC UA are also relevant to use.
- Discuss especially Data Security issues within the different platforms and protocols
- Give an overview of the Dimension Four IoT platform and their existing API. Make a detailed list of pros and cons and suggest a list of improvements and give examples how these can be implemented.
- Development of APIs and practical examples that communicates with the Dimension Four IoT platform, both datalogging (publishing data) and monitoring/visualization (retrieving data) of data for the programming platforms Visual Studio/C#, Python, LabVIEW, and MATLAB. Julia may also be an alternative, as well as ASP.NET Web Applications for presentation of data.
- The APIs and the practical examples should be tested out on different devices such as standard Windows PC with different DAQ devices from National Instruments, Arduino, and Raspberry Pi.

- Arduino: An open-source (GitHub) Arduino Library should be part of the solution
- Raspberry Pi: An open-source (GitHub) Python Library should be part of the solution
- Visual Studio/C#: An open-source (GitHub) Nuget package should be part of the solution
- LabVIEW: Open-source (GitHub) distribution via VI package Manager (VIPM)
- The APIs and the practical examples need to be investigated, tested, and explored thorough on practical applications within Home Automation and Industrial Applications. Here should also data analysis and presentation be in focus, e.g., Machine Learning.
- Compare and discuss the different IoT platforms and their features, advantages and disadvantages and suitable applications for the different IoT platforms.
- The APIs and the practical examples should be open source and should be available at GitHub.
- The different APIs and the practical examples need to be documented properly both as written documents (e.g., in GitHub), but also in form of videos available on YouTube.

Student category: IIA, both campus and online, but also for industry master students that want to take a project outside their own company.

The task is suitable for online students (not present at the campus): Yes. All work can be done online.

Practical arrangements:

Necessary resources and help will be provided by Dimension Four.

External partner (Dimension Four) will be responsible for providing a sensor for the project that will grade the work in collaboration with the supervisor from USN.

The resulting report should be public available.

Supervision:

As a general rule, the student is entitled to 15-20 hours of supervision. This includes necessary time for the supervisor to prepare for supervision meetings (reading material to be discussed, etc).

Signatures:

Supervisor (date and signature):

Student (write clearly in all capitalized letters):

Student (date and signature):

Appendix B

Gantt Diagram

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