



\$GGLWLRQDOO\ LPPHUVLYH PDQLSXODWLRQ WKUHDWV ZHUH KLJKOLJKW  
D FRPSURPLVHG 95 V\WHP 0DQ\ SRWHQWLDO PLWLJDWLRQV ZHUH LGH  
DVVHVHVG IRU WKHLU HIIHFWLYHQHV DQG VXLWDELWLW\ IRU KHDOWK F  
XVDJH DQG JRYHUQDQFH RI ;5 IRU HDFK LQGLYLGXDO DSSOLFDWLRQ EDV  
LPSRUWDQW WR QRWH WKDW WKLV VFRSLQJ UHYLHZ ZDV OLPLWHG E\ WK

-0,5 ;5 6SDWLDO &RPSXWRL H

.H\ZRUB\EHUDWDFNV F\EHU GHIHQFH F\EHU VHFXULW\ H[WHQG HG UH  
F\EHUVHFXULW\

## Introduction

### Background

([WHQG HG UHDOLW\ ;5 LV D EURDG WHUP XVHG WR UHIHU WR  
DXJPHQWHG UHDOLW\ \$5 YLUWXDO UHDOLW\ 95 DQG PL[HG  
UHDOLW\ 05 RU D WHFKQRORJ\ WKDW FRPELQHV WKH XVH RI WKHP  
7KHVH WHFKQRORJLHV DUH GHILQH E\ WKHLU DELOLW\ WR H[WHQG  
WKH SK\VLFD ZRUOG ZLWK D YLUWXDO ZRUOG WR YDU\LQJ GHJUHHV  
GHSHQGLQJ RQ WKH VSHFLIL@WSSH RI ;5 WHFKQRORJ\ >  
HQKDQFHV WKH SK\VLFD ZRUOG E\ RYHUOD\LQJ YLUWXDO IHDWXUHV  
DQG IXQFWLRQDOLW\ ZKHUHV 95 LPPHUVHV WKH XVHU LQ D GLVWLQFW  
YLUWXDO ZRUOG RIWHQ WKURXJK D KHDG PRXQWHG GLVSOD\ +0'  
>@ ORUHRYHU DXGLR RXWSXW LV DOVR XVXDOO\ SUHVHQW DQG  
WRJHWKHU WKHVH VHQRU\ IHDWXUHV LPPHUVH WKH XVHU LQ D YLUWX  
ZRUOG WKURXJK YLVXDO DQG DXGLR FXHV 05 LV PLGZD\ EHWZHHQ  
95 DQG \$5 LQ ZLFLK WKH RYHUODLG YLUWXDO ZRUOG FRH[LVWV  
DQG LQWHUDFWV ZLW@WDFKSMWEKQORQH >  
SURLGHV D QHZ SDUDGLJP RI KXPDQ FRPSXWHU LQWHUDFWLRQ  
DQG LV GHVLJQH WR LPSURYH TXDOLW\ RI OLIH HLWKHU WKURXJK  
HQWHUWDLQPHQW RU DSSOLFDWLRQ LQ LQGXVWU\ DQG WKH ZRUNSODFH  
JURZLQJ DUHD RI 95 DSSO@FDWLRQV LV KHDOWK FDUH >

2QH H[DPSON RI 95 DSSOLFDWLRQV ZLWKLQ KHDOWK FDUH LV  
LQ WKH DUHD RI RFFXSDWLRQDO WKHUDS\ ZLFLK DLPV WR LPSURYH  
SDWLHQWV. TXDOLW\ RI LQGHSHQGHQW OLYLQJ WKURXJK DFWLYLWLH  
DQG H[HUFLVHV WDUJHWLQJ VSHFLILF PRYHPHQWV DQG IXQFWLRQV  
>@ &XUHQW PHWKRGV LQ RFFXSDWLRQDO WKHUDS\ XVH GLIIHU  
HQW WHFKQRORJLFDU UHVRXUFHV VXFK DV PHFKDQLFDU VHWXS WKD  
HPXODWH UHDO@LTHDFORVLEHVVHG WRROV VXFK  
DV YLGHV JDPHV DQG VHQRU EDVHG WHFKQRORJLHV DUH DOVR  
XVHG LQ FOLQ@FD@BQDFWKH;5 EDVHG WKHUDS\  
PHWKRGV 95 V\WHPV KDYH VKRZQ DQ LQFUHDVLQJ GHPDQG DQG  
KDYH VWDUWHG WR EH XVHG DV DQ DGMXQFW WR FRQYHQWLRQDO WKHU  
> @

+RZHYHU ;5 EDVHG KHDOWK FDUH LQWHUYHQWLRQV KDYH

DQG VRFLDO DFWLYLWLHV 7KHVH VHUYLFHV ZLOO OLNHO\ KDYH LVVXH  
PDLQWDLQLQJ WKH SULYDF\ DQG VHFXULW\ RI XVHU GDWD DW UHVV DQ  
LQ WUDQVLW RYHU WKH LQWHUQHW 7KHUH LV WKH SRWHQWLDO RI SU  
DQG LGHQWLI\LQJ LQGLYLGXDO GDWD EHLQJ H[SRVHG E\ \$, DQG  
0/ WUDLQHG RQ WKLV GDWD ,Q DGGLWLRQ JDPLILFDWLRQ H[SRVHV  
D QHZ YHFWRU ZKHUH LQGLYLGXDOV FDQ EH LQYDVLYHO\ PRQLWRUHG  
ERWK E\ RWKHU XVHUV LQ VRFLDO VLWXDWLRQV DQG PDOLFLRXV DFWR  
> @ :KHQ WKH GDWD EHLQJ JDWKHUHG DQG REVHUYHG LV JHQHU  
DWHG IURP XVDJH LQ KHDOWK FDUH VHUYLFHV WKLV FDQ SRWHQWLDO  
GLVFORVH KHDOWK DQG ELRPHWULF LQIRUPDWLRQ DERXW WKH XVHU  
> @ 6HFXUH FRPSXWDWLRQ WHFKQLTXHV VXFK DV EORFNFKDLQ  
DUH UHFRPPHQGHG WR PDLQWDLQ WKH LQWHJULW\ DQG FRQILGHQWLDO  
LW\ RI GDWD DORQJ ZLWK OHJDO SURWHFWLRQ RI OHWDYHUVH FROOHF  
WHG GDWD WKURXJK OHJLVODWLRQ VXFK DV WKH +HDOWK ,QVXUDQFH  
3RUWDELOLW\ DQG \$FFRXQWDEL@LW\ \$FW LQ WKH 8QLWHG 6WDWHV >

7DEO1RRJOH 6FKRODU VHDFK WHUP VWUDWHJ\

6HDFK TXHU\

-XVWLILFDWLRQ

SULYDF\ 25 VHFULW\ 25 DWDFN 25 W4XHDWIR5\ SHFXDF\ 25 QHFXEHQVH5XULW\ LVVX  
9LUWXDO UHDFW\ 25 DXJPHQWHG UHDFW\ 25 H5BLWHFKQDORW\ 25 LQWHSQHG  
UHDFW\

7KUHDW WDUJHW RSWLRQDO W@HV(DFKUKDQFWLRRX DDE B KIPHDWUJHDP H  
GHOLQHDWHG EDVHG RQ WKHLUZROWHHQBDEHOHMHFWH VDFK KRUUV WR FR  
PDQLSXODWLRQ RI WKH XVHU DU R LQWLHQWH B QW BU JFRXQXFK K PD HDVXUH  
WKH SULYLOHJH OHYHO WKDW WKH F\EHUWDFFXWDWUJH SRVWXUH RI D KHD  
7KH 1,67 &\EHUVHFXULW\ )UDPHZRUN LYL FRPPSULYHGFR RI FRUH  
IXQFWLRQV IRU RUJDQL]DFWLRQWHFWULDGGUHV V WKHLU  
PHDVXUHV LGHQWLI\ SURWHFW GHWHFW UHVSRRG DQG UHFRYHU

7DEOHDWLRQDO ,QVWLWXWH RI 6WDQGDUGV DQG 7HFKRORR@ F\EHUVHFXULW\ IUDPHZ  
)UDPHZRUN IXQHVLQRQLRQ

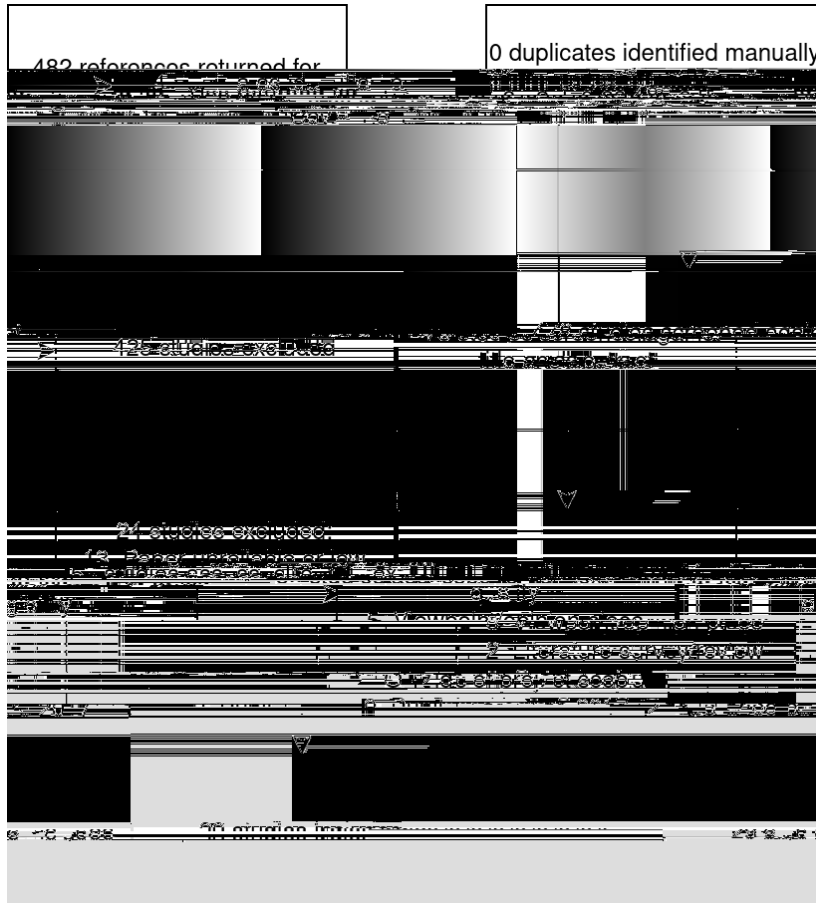
|          |  |
|----------|--|
| ,GHQWLI\ | ,QFOXGHV FDWDORJLQJ DQG XQGHUVWDQGLQJ WKH DVVHWV EXVLQHVV<br>LPSOHPHQWLQJ SROLFLHV DQG SURFHGXUHV IRU PDLQWDLQLQJ F\EHUV               |
| 3URWHFW  | 5HJDUGV LPSOHPHQWLQJ WHFKQLFDO DQG VWUDWHJLF PLWLJDWLRQ V\<br>F\EHU LQFLGHQW ZKLFK PD\ LQYROYH LPSOHPHQWLQJ DFFHVV FRQWUR              |
| 'HWHFW   | ,QYROYHV LPSOHPHQWLQJ WHFKRORJLHV DQG VWUDWHJLHV WR GHWH<br>LPSOHPHQWLQJ FRQLQXRXV PRQLWRULQJ VRIWZDUH RQ DVVHWV DQG                   |
| 5HVSRRG  | ,QYROYHV LPSOHPHQWLQJ WHFKRORJLHV DQG VWUDWHJLHV WR UHVS<br>LQFLGHQW UHVSRRQH SODQV DQG F\EHU IRUHQVLF FDSDELOLWLHV                    |
| 5HFRYHU  | 5HJDUGV LPSOHPHQWLQJ DQG VWUHQJWKHQLQJ UHFRYHU\ DELOLW\ GX<br>LQFOXGH LQFRUSRUDWLRQ OHVVRQV OHDUQHG IURP WKH LQFLGHQW LG<br>SURFHGXUHV |

:KLOH WKH 1,67 &\EHUVHFXULW\ )UDPHZRUN DQG FINEHFWLW WDIRUV LGHQW  
FRPPXQLFDWLQJ PLWLJDWLRQV DQH(5OX PD RPH ZRGN RRUV HHDIF K FFDLVHJR U\  
IRU DUWLFXODWLQJ DQG RUJDQL]LQJ ULNVN WR DQ RUJDQL]DWLRQ LQ W  
FDVH D KHDOWK FDUH RUJDQL]DWLRQ 7R WKLV HQG FDWHJRULHV ZHU  
VHOHFWHG WR DUWLFXODWH RUJDQL]DWLRQDO ULNVN SUHVHQWHG E\ F  
WKUHDWV WR D KHDOWK FDUH RUJDQL]DWLRQ ORRNLQJ DW LPSOHPHQW  
FOLQLFDO ;5 V\VWHPV FRPSOLDQFH ZLWK DSSOLFDEOH UHJXODWRU\  
PHDVXUHV DELOLW\ DQG FDSDFLW\WKHWHGHOWYHU KDPQWVJHUKLFFM F  
FRQILGHQFH RI WKH FRPPXQLW\ DQG VWDNHKROGHUV LQ WKH KHDOWK  
FDUH RUJDQL]DWLRQ ILQDQLDO SHUIRUPDQFH DQG ZRUNSODFH  
KHDOWK DQG VDIHW\ 3RWHQWLDOO\ VLJQLILFDQW ULNVN SRVHG E\ WK

Results

Search Results

)LJXUHWXG\ H[WUDFWLRQ DQG VHOHFWLRQ SURFHVV IROORZLQJ 35,60\$ 35,60\$ 3UHH  
VHV



7DEOH6HWXG\ FROOHFWLRQ DQG H[FOXVLRQ SURFHVV VXPPDU\

1XPEHU RI VWXGLH

6HDUFK WHUPROXVHFWLRQ

SULYDF\ 25 VHFUXULW\ 25 DWDFN 25 WKUHDW 25 VHFUXH 25 VHFUXULQJ \$1' 9LUW  
PL[HG UHDOLW\ 25 H[WHQG UHDOLW\

DFFHV FRQWURO 25 VLGH FKDQQHO 25 XVHU SURILOLQJ 25 WUDFNLQJ XVHU ORFD  
DXJPHQWHG UHDOLW\ 25 PL[HG UHDOLW\ 25 H[WHQG UHDOLW\

VXUYH\ DUFKLWHFWXUH 25 DQDO\VLV KHDOWKFDUH \$1' 9LUWXDO UHDOLW\ 25 D  
UHDOLW\

5HDVRQV IR[FHFWLRQ

\$EVWUDFW VFUHHQLQJ

3DSHU XQUHOLDEOH RU ORZ TXDOLW\

9LHZSRLQW RSLQLRQ SLHFH

/LWHUDWXUH VXUYH\ UHYLHZ

2XWVLGH RI SURMHFW VFRSH

3XEOLVKHG EHIRUH

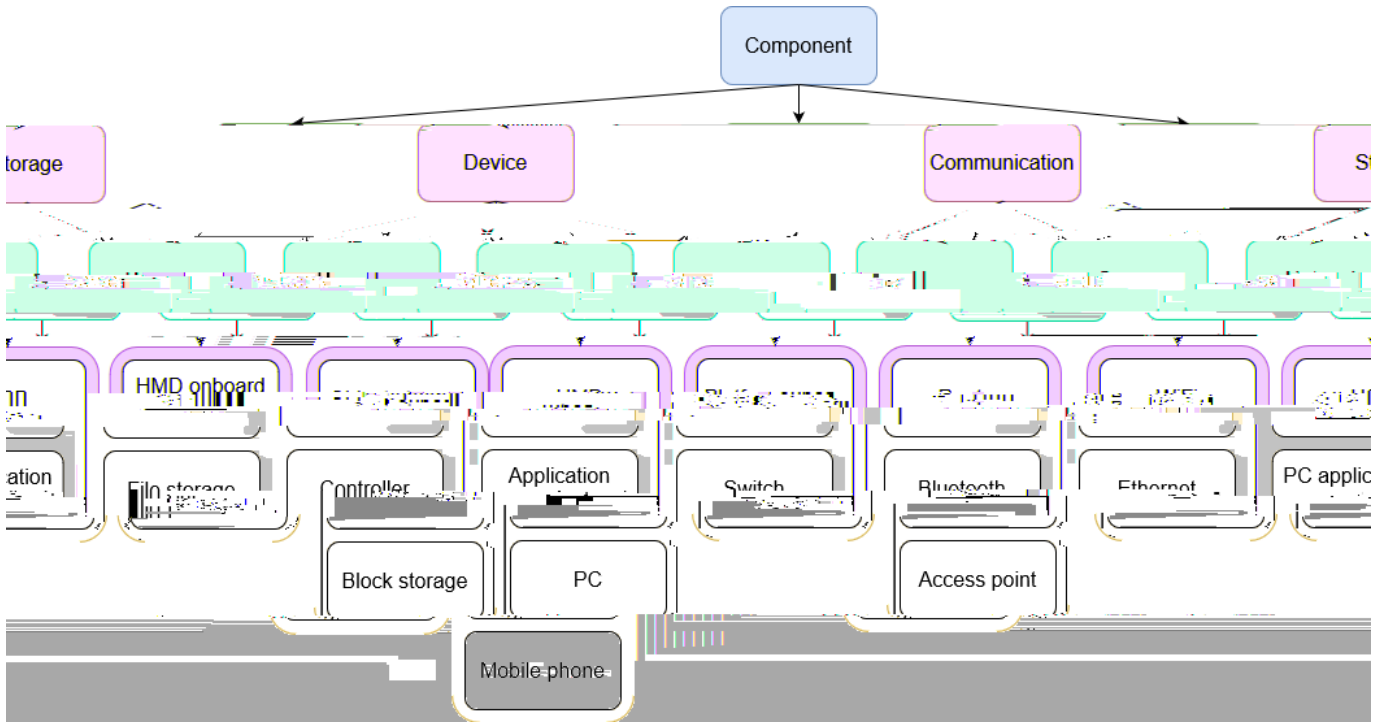
## Study Characteristics

### Publication Statistics

7KH OLWHUDWXUH VHUFK ZDV UHVWULFWHG WR VWXGLHV SXEOLVKH  
EHWZHHQ DQG \$ WRWDO RI DUWLFOHV ZHUH LQLWLDOO\

LQ WKH WLWOH H[F@SDW@ZRD@RUHW D>O  
> @ ZDV FODVVLILHG DV RWKHU ;5 VLQFH WKH VWXG\ IRFXVHG RQ  
WKH 0HWDYHUVH DQG WKH SDS@U E\ /HWDIDWL DQG 2WRXP >  
ZDV FODVVLILHG DV 95 \$ SDSHU FRXOG IRFXV RQ PRUH WKDQ  
RQH GLPHQVLRQ DQG VR FRXOG EH FRXQWHG PRUH WKDQ RQFH \$  
VLJQLILFDQW QXPEHU RI SDSHUV IRFXVHG RQ 95 SDSHUV EXW  
PRVW IRFXVHG RQ RWKHU ;5 WHFKQRORJLHV SDSHUV

)LJXU&ODVVLILFDWLRQ RI H[WHQG HG UHDOLW\ FRPSRQH QW W\SHV +0' KHDG PRXQWH



7DEO3URRI RI FRQFHSW GHYLFH XVDJH FRXQW DFURVV VWXGLHV

3URRI RI FRQFHSW GHYLFH

1XPEHU RI SDSHUV

2FXOXV 5LIW

0HWD 4XHVV

0HWD 4XHVV

+7& 9LYH

6DPVXQJ \*HDU

0RELOH

2WKHU

!v HG LGHQWLILHG XQLTXH DWWDFNVAESFDWLEWRE DRD;SOG RPDQVLDVHG F  
FDQ EH VHHQ LQ WKH HOWPFDLFDSSRGU

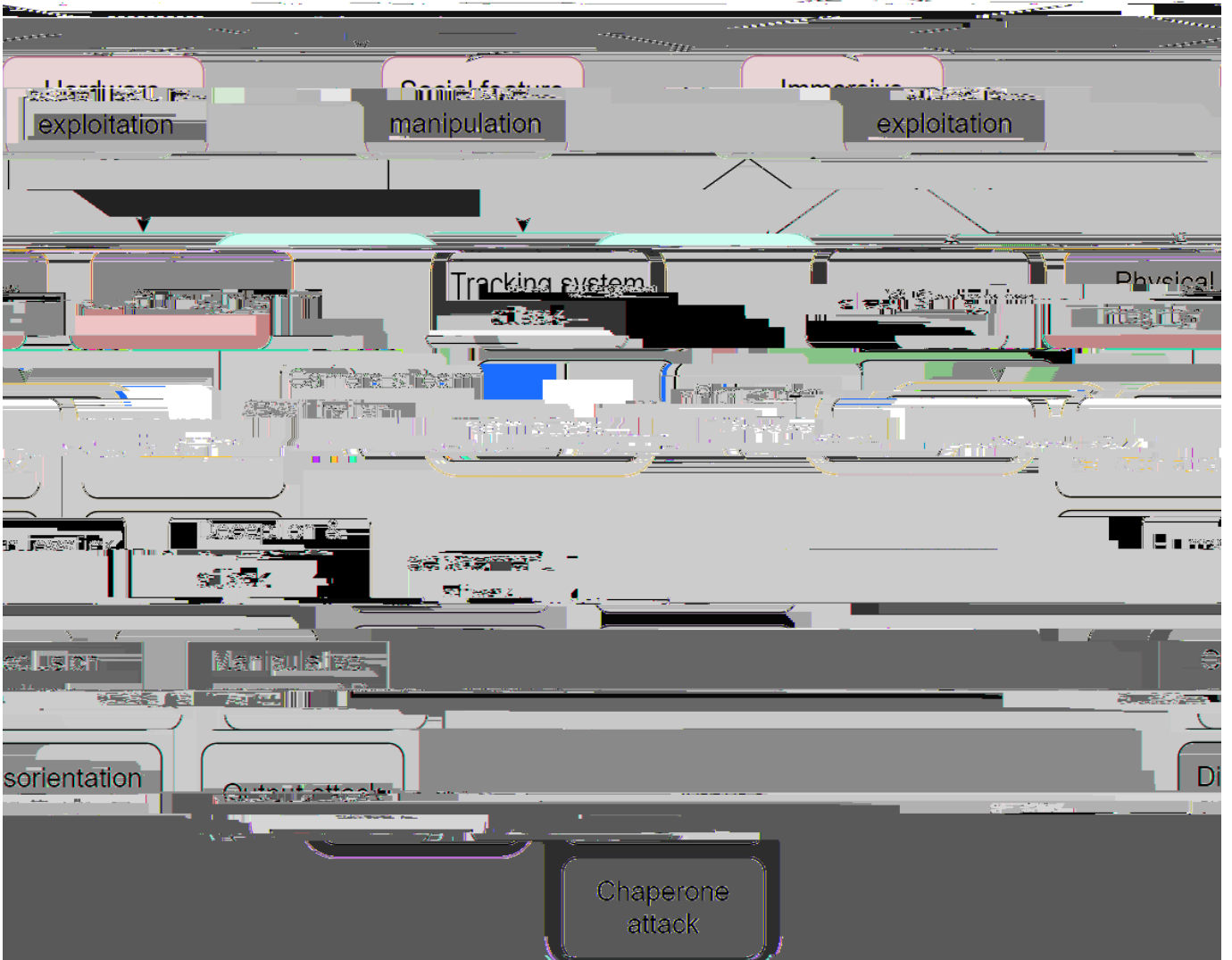
7KH VHFUXULW\ WKUHDW WD[RQRP\ DQG DWWDFNV FODVVLILHG LQ

)LJXUZHUH GHYHORSHG IURP WKH OLWHUDWXUH UHYLHZ DQG E\  
DQDO\]LQJ WKHVH DWWDFNV DV GHVFULEHG LQ 0HWKRGV 6HFXULW\  
WKUHDWV VSHFLILF WR ;5 FRPSRQH QWV DUH WKRVH WKDW LQYROYH  
DQ H[SOLFLW WDP SHULQJ LQWUHVLRQ RU EUHDNDJH RI WKH



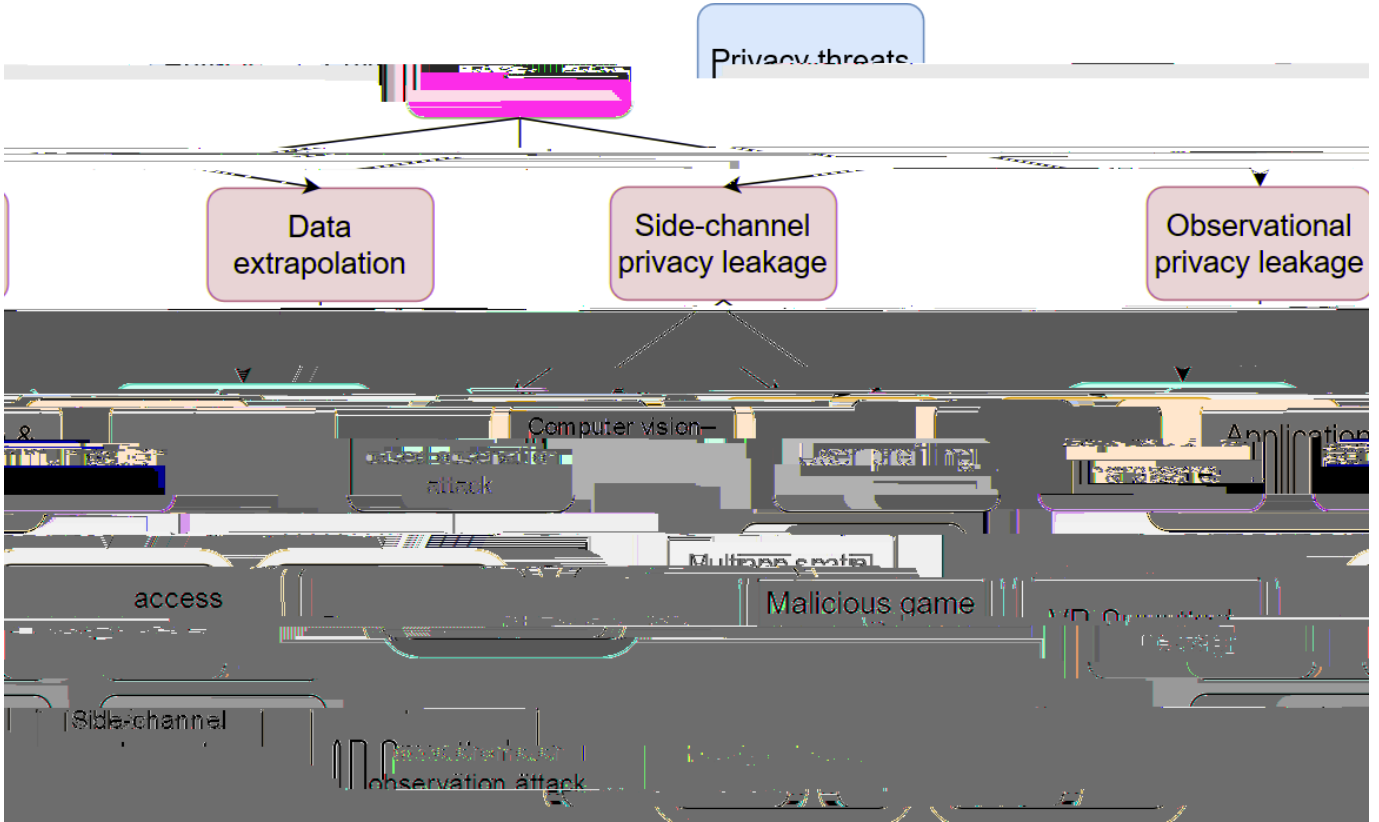
)LJXU6HFXULW\ W KUHDW WD[RQRPI\ DQG DVVRFLDWHG DWWDNFV \$5 DXJPHQWHG UHD

Security threats



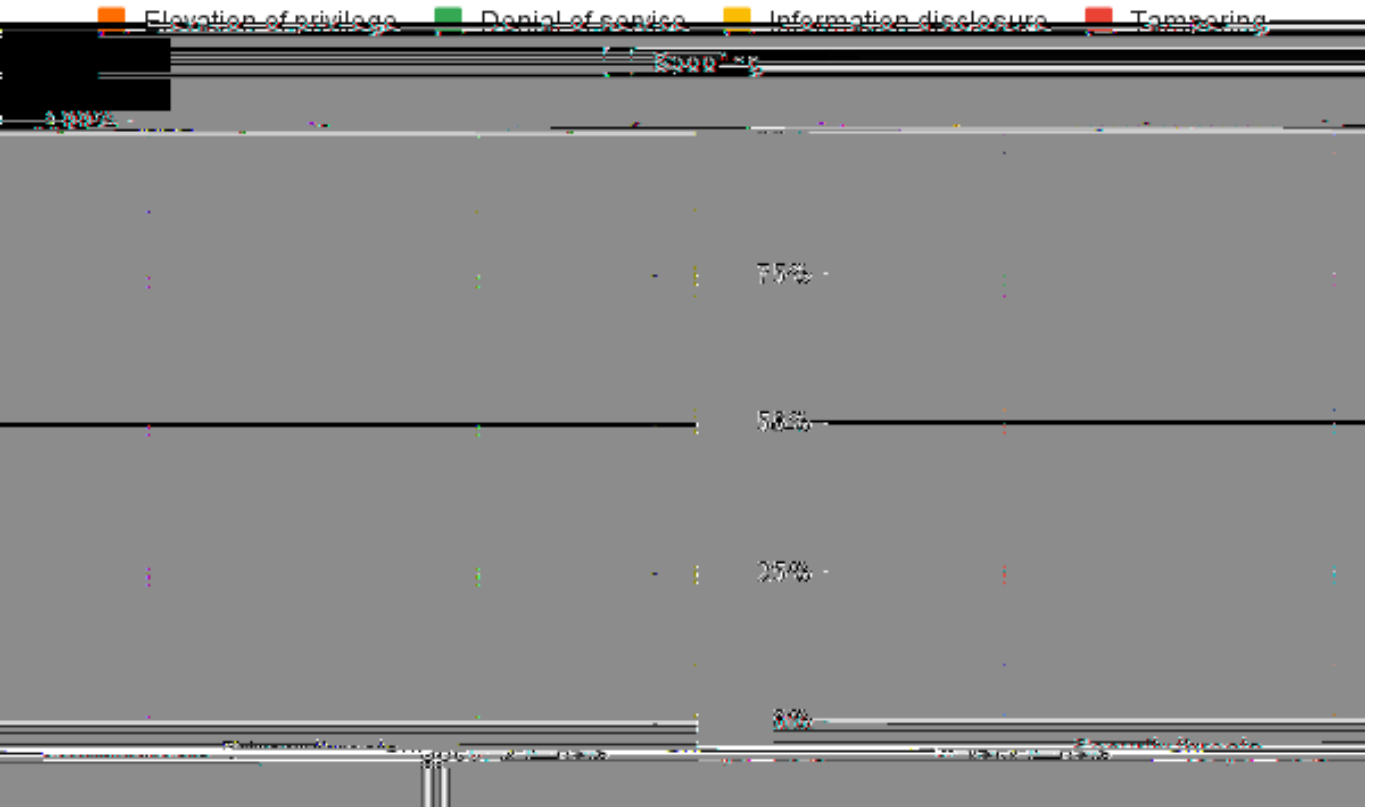
, PPHUVLYH PDQLSXODWLRQ FRQVWLUWHX WWHKR VMKW KPDDM FDULHW L QRW HVOGHTED W  
 DQG F\EHUDWWDNFV LGHQWLILHG WQL ROK HZ LOW W HULDPW WWHIG WRRL VQ RI QW B P S E V  
 DQ\ W KUHDW WKDW XWLOLJHV W KHWHQL TX KH H H B WQ LEHV ERU RDDG OS V IDWVLRQL  
 WDUJHW WKH V HFXULW\ RI W KH V\DW B R DRUH V DEHW U RD WLRQ D OHSJU LYKDFH DO  
 WKDW WDUJHW SK\VLFDQ LQWHJU L W L YDIFI W KH W H J M KW H M HULV WRR DSK\ VLRQ  
 PDQLSXODWH RU LPSDFW D XVHU L Q DFKY HDUWHQ FDOXV O Q D NF HGH D QIG N R W F  
 QHVV DQG SK\VLFDQ FROOLVLRQ ZLW K UHPDQG IZ R D O G R EMMWDFNFV >R Q D V  
 7KUHDWV WKDW WDUJHW RXWSXW O G D M D U H W H L B E O XGR S O L Y D K U H D W M D D  
 WR LPSDFW RU GHJUDGH WKH V H G V H G U H H V W W U R I V W R K H D Q H I E R Q L E V D O Y B H V  
 VHVLRQ 7KH\ LQFOXGH GHFHSWR RND QG F O K I D F L H P K I Q W K D S V H D E N D W W  
 ZKLFK ZHUH IRXQG WR KDYH WKH O S R W O H Q W L D R O P P X R Q L L P D S D I E R Q X O H Y H O 2  
 PHQWDO DQG HPRWLRQDO ZHOO E H I L Q F R I E S D R X W H S X D W W W O F N L Q D S S O U R S U M H V  
 RU XSVHWWLQJ YLVXD@RU DXGLR X R Q W H R W B Q ;5 XVHU REVHUYLQJ EIV  
 PHQW 'DWD HIWUDSRODWLRQ LQFOXG  
 7KH SULYDF\ W KUHDW WD[RQRPI\ DQG DVVRFLDWHG DWWDNFV V H H O  
 LQLJXUZHUH GHYHORSHG IURP W KH O L W H T U R P F R O O H E W H G '5 GDWD  
 GHVFULEHG LQ OHWKRGV 3ULYDF\ W KUHDWV WR ;5 FRPSRQHGW

)LJXU3HULYDF\ WKUHDW WD[RQRP\ DQG DVVRFLDWHG DWWDFNV



7KH W\SH RI LQIRUPDWLRQ WKDW REEDUHQH YHDWRB QHFHWWHG HDQGLDQY LQIRUPDWLRQ  
 DERXW XVHUV LQ WKHVH DWWDFNV WKHQ XQH V ELRPHWULF GDWD SV\FK  
 ORJLFDO GDWD DQG SHUVRQDOO\ LGHOWLILDEOH LQIRUPDWLRQ VXFK  
 DV > @ FRORU EOLQGQHVV PHQWDO & EHO WKUHDW WR 5 DERPSRQH QWV  
 VWDWXV SK\VLFD ILWQHVV PHQWDO & FXIWLILHG VLJKW HUPOLM WKH 6  
 DFXLW\ 7KH VWXG\ @\G1HPLRQ VWUDWV LGH FODYVLILHG LQWR PRUH WKDQ  
 FKDQQHO SULYDF\ OHDNDJH DWWDFNV WKHQ 95 HJDPH WKDW FDQ  
 LQFRQVSLFXRXVO\ KDUYHVV VXFK LGH FODYVLILHG LQWR PRUH WKDQ  
 SURILOLQJ IUDPHZRUN LQYROYLQJ LGH FODYVLILHG LQWR PRUH WKDQ  
 WR H[WUDSRODWH VXFK GDWD Z@V GHYHORSHG LHSXGLFRRO QP GHV  
 ZLWK KLJK PHQWDO ZRUNORDG WDVNKH ZEV@ VMHWWW WR ROLQJ IRK@GWR RV D  
 EH WKH PRVW HIIHFWLYH FRPELQDSULRQ FIR D WDDDFN V REO OWHFWLLR 67.5X KHFR  
 DWWDFNV JHQHUDOO\ GR QRW UHTXIHHP DQR UH[VV VRLQJH EQR WR DWKLRQ  
 UHODWHG WR WKH XVHU WR EH DVRG HMKRQP DMRUGWYLRH SULYDB\ WKKLU  
 WR EH D OLN WR WKHLU VRFLDGLRHFGRV XDFFRXQMDWKHVH SULYDF\  
 DWWDFNV RQO\ UHTXLUH WKH GDWD JHQHUDWHG E\ WKH ;5 V\VWHP RU

)LJXU&RQVWLWXWLRQ RI VHFUXULW\ DQG SULYDF\ WКУHDWV E\ 675,'( FODVVLILFDWLRQ



\*DUULGR @WD QG >DULQ DQG @ GHLYHQSDUSGFMV\VLQJ GLVWULEXWHG KHDOWK  
 DQDWW DSUNLYWLOHHYHOD VVL IIRFQSVL &Q FZKF\ LGHQWLILHG WKH SULPDU\ FKDO  
 DW W \$ FNKP P DRUW KHE VHU & D DOW UD @ GW HV EHLQJ PDLQWDLQLQJ WKH VHFU  
 GDWB XUIRHWV FKH YHDE HV HHL @ XOWL PB QGD SURFHVVHG WKH SULYDF\ RI WK  
 \$SSHQGZ\ KH DW HGLIHWNSRMD WWDENRIUXVHUV DV WKH\ DUH PRQL @ RWK I  
 KDUGZDUH OHYHO DWWDFNHU SULY,6 Q HJUL YD VFW D) RNDPH ZR LFND QD FF HW RRV  
 ORZ OHC \$DQV XWS \$ KJQDOWK +D' GHYLFHQ RUJDQLJDWLRQ DQG LPSURYLQJ JF  
 DFOLHQD VOM \$ IDHYLDWH DFRISUUDWHQ G SURFHVVHV 7KHUH DUH WLHUV  
 DQDSSOLFCHYHSD QFFHWKXVWDEPWWDLRQ WKDW GHOLQHDWH WR ZKDW H  
 SURJUDRQLVHJUDV FHUW HD V WDSO HYL DEHW HJDWH SULYDF\ ULVNV WKH ORZH  
 DWW D, F, F DFFRVRQ WUKHSOLF DW YRQLRQ LV ULVN LQIRUPHG EXW LPSOHP  
 DQGXVHU O WYHDE R @ USUDYLW DLENF OXSHLYDF\ +HDOWK FDUH RUJDQLJDWLR  
 DQ\ DWWDFNHU WKDW FDQ DFFHVW ISXUE OG XHW W @ H P @ V X L Q R I @ D W D X D Y W L L  
 DVRFDS \$ SOLFDW KRQ W W W K R V R P P R Z K L F K P H D Q V O L P L W H G P L W L J D W L R Q V  
 OHYH IORFF @ W W K F O L @ G W H O R I D W W D \$ F V G D W D D U H D W D K L J K H @ U \$ V N H W K I  
 DQ @ K O H D F R V P P R Q W D F N Y H O H U Y H @ D O V R L G H Q W L I L H G G D W D V H F X U L V  
 R I D W W D F N V R P M W X G I S O L Y W D W K H K D O O H Q J H V I R U X V L Q J \$ 5 L Q K H D O W K  
 S U L Y L O H Y H I V K H L G U H Q V D L W M H D Q V K R W K I D W , & I E H U V H E X U L W \ D Q G S U L Y D F \ W K U H D  
 G L G Q R W Z H U H F D W H J R U L J H G E D V H G R Q W K H L U I H D W X U H V  
 L Q W K H W K U H D W W D I R Q R P L H V D Q G W  
 2QO\ VWXGLHV GHVFULEHG F I E H D V H F X U W W L Q Q @ F S O H E H D F H P O S X H W K H V  
 R I ; 5 L Q D K H D O W K F D @ H F R O M E M D L Q Q @ D Q ( 5 0 P R G H O I R U P D Q D J L Q J  
 2W R X P @ > H [ S O R U H G W K H V H F X U L W O L N G L @ L B R Y G D @ Q @ L L V S D F W Q R I H D F K U L  
 S R W H Q W L D O P L W L J D W L R Q V R I L Q F R Q S R K I D W I S Q F K I H B O W H O F V K H F B D S I D E R Q I  
 L Q W R W K H O H W D Y H U V H D V L W U H O D W H B S W R W S B W L H Q W G D W D I O R Z D Q

7DEO(QWHUSULVH ULVN PDQDJHPHQW IUDPHZRUN PDSSLQJ RI H[WHQG HG UHDOLW\ F\E

675,'( WKUHDW 0LWLJDWLRQ 0LWLJDWLQJ WHFKQRORJ\  
5HSXGLDWLRQ 1RQUHSXGLDELPHWUGZDUH XVDJH@LQGLFDWRUV >  
,QIRUPDWLRQ G&R@L@R@H@MLDO@W\IHUHQWLD@SULYDF\ >  
‡%HKDYLRUDO P@GLILFDWLRQV >  
‡/RFDWLRQ EDVHG H[WHQG@H@UHDOLW\ XVDJH UHVWUL  
REVHUYDWLRQDO @SULYDF\ OHDNDJH >  
‡\$XWRPDWHG FRQWH[WXDO @ZDUHQHV DQG UHVSQV  
‡+HDOWK FDUH LQWHO@JHQW VHF@XULW\ PRGH >  
'HQLDO RI VHUYSYDL@LODEL@LW\ ‡'HVLJQ ZLWK WKH SULQ@LSOH RI UHG@XQG@DQF\ >  
‡,QWUXVLRQ GHWHFW@RQ V\@VWHPV >  
‡+HDOWK FDUH LQWHO@JHQW VHF@XULW\ PRGH >  
(OHDWLRQ RI \$@WK@R@L@J@DWLRQ @SSOLF@DWLRQ DFFHV@R@QWURO >  
‡'HVLJQ ZLWK WKH SULQ@FLS@H RI OHDVW SULY@LOHJH >

7DEOH,69F\EHUVHF@XULW\ IUDPH@ZRUN PDSSLQJ RI PLWLJDWLRQV IRU D KH@DOWK FDUH F  
)XQFWLRQ@FRSH

WR LQIRUPDWLRQ GLVFORVXUH WKUHDWV VXFK DV E\ UHVWULFWLQJ  
PRELOH \$5 XVDJH LQ D KRVSLWDO WR SURWHFW RFFXSDQW SULYDF\  
> @

&\EHU GHIHQVH WHFKQRORJLHV DQG PLWLJDWLRQ VWUDWHJLHV FDQ  
DOVR EH PDSSHG DJDLQVW RI WKHVH IXQFWLRQV SURWHFW GHWHFW

LQ KRVSLWDOV ZLWK FRQVLGHUDWLRQV RQ WKH FRPSOLDQFH ZLWK

DQQGLYL5KJXODWLRQV OHJLVODWLRQV DQG SROLFLHV H[LVW WR  
SURWHFW XVHUV DQG SURIHVVLRQDOV IURP WUDGLWLRQDO DQG JHQH  
ULVNV WR SULYDF\ DQG VDIHW\³VXFK DV WKH \$XVWUDOLDQ +HDOWK  
3UDFWLWLRQHUV 5HJXODWRU\ \$JHQF\ &RGH RI &RQGXFV ZKLFK  
PDQGDWHV SDWLHQW VDIHW\ EH PDGH D SULRULW\ DQG ULVN PDQ  
DJHPHQW SUDFWLFH@ DQG GR-CHDZMIG >QVXUDQFH  
3RUWDELOLW\ DQG \$FFRXQWDELOLW\ \$FW OHJLVODWLRQ LQ WKH 8QLW  
6WDW@VEXW WKHVH IUDPHZRUNV PD\ QRW EH GHVLJQHG IRU  
WKH QRYHO XQLTXH DQG JURZLQJ WKUHDWV SRVHG E\ ;5 7KLV  
PD\ SRVH OHJDO DQG HWKLFDO GDQJHUV IRU D KHDOWK FDUH RUJDQL]D  
WLRQ DV DOVR PHQWLR@HG KLVORRVRW@JHW DO >  
WKUHDW ODQGVFDSH PD\ PDNH WKH HWKLFDO FRQVLGHUDWLRQV RI XVLO  
>5 WHFKQRORJ\ LQ KHDOWK FDUH PRUH FRPSOH[ DQG KLJKOLJKWV  
WKH IDFW WKDW WKH F\EHUVHFXULW\ SRVWXUH LQ DOO GRPDLQV RI KHD  
FDUH PXVW EH SURDFWLYH UDWKHU WKDQ UHDFWLYH WR DYRLG OHJD



7KH DXWKRUV FRQWULEXWHG WKH IROORZLQJ WR WKL V ZRUN DFFRUGLQJ  
WLRQ PHWKRG RORJ\ YDOLGDWLRQ IRUPDO DQDO\VLV LQYHVWLJDWLRQ  
DQG HGLWLQJ DQG YLVXDOLJDWLRQ \$0. ZDV LQYROYHG LQ WKH FRQFH  
HGLWLQJ VXSHUYLVLRQ SURMHFW DGPLQLVWUDWLRQ DQG IXQGLQJ DF  
LQYHVWLJDWLRQ ZULWLQJ RULJLQDO GUDIW ZULWLQJ UHYLHZ DQG  
FRQFHSWXDOLJDWLRQ ZULWLQJ UHYLHZ DQG HGLWLQJ VXSHUYLVLRQ  
JDWLRQ DQG ZULWLQJ UHYLHZ DQG HGLWLQJ -) ZDV LQYROYHG LQ WK  
DFTXLVLWLRQ 1% ZDV LQYROYHG LQ WKH FRQFHSWXDOLJDWLRQ ZULWL  
IXQGLQJ DFTXLVLWLRQ ". ZDV LQYROYHG LQ WKH FRQFHSWXDOLJDWLRQ  
VXSHUYLVLRQ DQG IXQGLQJ DFTXLVLWLRQ

---

Conflicts of Interest

1RQH GHFODUHG

Multimedia Appendix 1

(OHFWURQLF GDWDEDVH VHDFK VWUDWHJ\

>

0F1DPDUD . %R \$3/ 0F.LWWULFN \$ 7RUQDWRUH \* /DUDF\ 6 'HVVHOO  
XSSHU OLPE PRYHPHQW GXULQJ UHKDELQDWRQ XVLQJ YLGHJ JDP  
RQ 6HULRXV \*DPHV DQG \$SSOLFDWRQV IRU +HDOWK 6H\*\$+ \$XJ  
6(\*\$+ @  
=KDQJ % %R \$3/ 0F.LWWULFN \$ HW-DO +DQG\ MXLFH EDU D KDQG U  
WUDFNLQJ 3UHVHQWHG DW ,((( WK ,QWHUQDWRQDO &RQIHUHQ  
6H\*\$+ \$XJ 6\GQH\ \$XV\*U\$+OLD >GRL@  
0F .LWWULFN \$ 'HVVHOOH 05 3DGLOKD /DQDUL %R \$ =KDQJ % /DUDF  
FRQWUROOHU IUHH KDQG WUDFNLQJ YLUWXDO UHDOLW\ WDVNV IRU X  
>GRL @ >0HGOLQH@  
1DLU 9 \*XR : 0DWWHUQ - HW-DO 8QLTXH LGHQWLILFDWRQ RI



3ULYDF\ DQG 6HFXULW\ \$XJ KWWSV [U MPLU RUJ @  
 >\$FFHVHVG @  
 \*XOKDQH \$ 9\DV \$ 0LWUD 5 HW-DO 6HFXULW\ SULYDF\ DQG VDIHW\  
 DSSOLFDWLRQV 3UHVHQWHG DW WK ,((( \$QQXDO &RQVXPHU &R  
 /DV 9HJDV 19 86&&1&GRL @  
 9DOOXULSDOO\ 6 \*XOKDQH \$ 0LWUD 5 +RTXH .\$ &DO\DP 3 \$WWDFN  
 OHDUQLQJ HQYLURQPHQWV 3UHVHQWHG DW ,((( WK \$QQXDO &R  
 &&1& -DQ /DV 9HJDV 19&&8&\$ >GRL @  
 \$UDIDW \$\$ \*XR = \$ZDG \$ 95 VS\ D VLGH FKDQQHO DWWDFN RQ YLUW  
 ,((( 9LUWXDO 5HDOLW\ DQG ' 8VHU ,QWHUIDFHV 95 0DU WR \$SU  
95 @  
 &KHQ 6 /L = 'DQJHOR ) \*DR & )X ; \$ FDVH VWXG\ RI VHFUXULW\ DQG  
 3UHVHQWHG DW ,QWHUQDWLRQDO &RQIHUHQFH RQ &RPSXWLQJ 1  
 ODXL +, 86\$ >GRL1& @  
 6LULZDUGKDQD < 3RUDPEDJH 3 /L\DQDJH 0 <OLDQWWLOD 0 \$ VXUYH  
 FRPSXWLQJ DUFKLWHFWXUHV DSSOLFDWLRQV DQG WHFKQLFDO DVS  
 >GRL &2067 @  
 6\DO 6 0DWKHZ 5 7KUHDWV IDFHG E\ PL[HG UHDOLW\ DQG FRXQWHUP  
M SURFV @  
 :DQJ < 6X = =KDQJ 1 HW-DO \$ VXUYH\ RQ 0HWDYHUVH IXQGDPHQW  
 7XWRULDQV &2067 @  
 'LFN ( %DODQFLQJ XVHU SULYDF\ DQG LQQRYDWLRQ LQ DXJPHQWHG D  
 )RXQGDLRQWS\ /LWLI RUJ SXEOLFDWLRQV EDODQFLQJ XVHU  
YLUWXDO >\$FFHVHVG @  
 6KDUHG &RGH RI FRQGXFW \$XVWUDOLDQ +HDOWSV3U DFWDSRQ HURVHD  
&RGH RI FRQGXFW 6KDUHG >\$FFHVHVG FRQGXFW@DVS]

Abbreviations

\$, DUWLILFLDO LQWHOOLJHQFH  
 \$5 DXJPHQWHG UHDOLW\  
 'R6GHQLDO RI VHUYLFH  
 (50 HQWHUSULVH ULVN PDQDJHPHQW  
 +0' KHDG PRXQWHG GLVSOD\  
 0/ PDFKLQH OHDUQLQJ  
 05 PL[HG UHDOLW\  
 1,671DWLRQDO ,QVWLWXWH RI 6WDQGDUGV DQG 7HFKQRORJ\  
 35,60\$ 6F5UHIHUHG 5HSRUWLQJ ,WHPV IRU 6\WHPDWLF UHYLHZV DQ  
 675,'(VSRRLQJ WDPHULQJ UHSXGLDWLRQ LQIRUPDWLRQ GLVFORV  
 95 YLUWXDO UHDOLW\  
 ;5 H[WHQG HG UHDOLW\

(GLWHG E\ 7LIIDQ\ /HXQJ SHHU UHYLHZHG E\ 'L[LW 3DWHO 6XEDVUL &KHOOD  
 YHUVLRQ UHFHLYHG DFFHSHWG SXEOLVKHG  
 3OHNVH FLWH DV  
 /DNH . 0F .LWWULFN \$ 'HVVHOOH 0 3DGLOKD /DQDUL %R \$ \$ED\DV LUL 5\$0  
 &EHUVHFUXULW\ DQG 3ULYDF\ ,VXHV LQ ([WHQG HG 5HDOLW\ +HDOWK &DUH \$  
 -0,5 ;5 6SDWLDQ &RPSXW H  
 85/ KWWSV [U MPLU RUJ  
 GRL

< .DLWO\Q /DNH \$QGUHD 0F .LWWULFN 0DWKLOGH 'HVVHOOH \$QWRQL  
 )OHPLQJ 1LOXIDU %DJKDHL 'DQ 'RQJVHRQJ .LP 2ULJLQDQ KWWSV [U MPLU RUJ  
 7KLV LV DQ RSHQ DFFHV V DUWLFOH GLVWULEXWHG XQG KWWSV [U MPLU RUJ  
FUHDWLYHFRPPRQV RUZKDORHSHUPLWV XQUHVWULFWHG XVH GLVWULEXW

WKH RULJLQDO ZRUN ILUVW SXEOLVKHG LQ -0,5 ;5 DQG 6SDWLDO &RPSX  
WLRQ D OLQN WR WK [KRWBJLQDO SXEOLFD](#) WLRQ RQ